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A MANUAL

OF

AGRICULTURAL CHEMISTRY,

&c. &c.

A MANUAL

OF

AGRICULTURAL CHEMISTRY,

WITH ITS APPLICATION TO

THE SOILS OF IRELAND.

BY

THOMAS ANTISELL,

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THE FOLLOWING PAGES,

INTENDED

TO AID IN ADVANCING A MORE SCIENTIFIC EDUCATION

AMONG THE FARMERS OF IRELAND,

ARE DEDICATED TO

DR. ROBERT KANE, M.R.I.A.,

HONORARY MEMBER OF, AND PROFESSOR OF NATURAL PHILOSOPHY TO
THE ROYAL DUBLIN SOCIETY;
PROFESSOR OF CHEMISTRY IN THE SCHOOL OF MEDICINE,
CECILIA-STREET, ETC. ETC.,

AS A SMALL TRIBUTE TO HIS VARIED TALENT, AND

AN EVIDENCE OF PERSONAL ESTEEM, FROM

THE AUTHOR.

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PREFACE.

The object of the following little Treatise is to convey to the Irish farmer an outline of the science which he cultivates, while, at the same time, those peculiarities of soil and climate which require to be known previously, in order to be guarded against, are communicated in as clear and concise language as the nature of the subject will admit of.

The general attention which has, of late years, been bestowed upon this hitherto neglected science, has produced many changes, both in opinion and practice, among agriculturists. Much that was previously deemed true and impregnable, has been assailed, and become a matter of doubt; new views of many of the processes of the vegetable world have been expounded, and old hypotheses exploded. Analytic chemistry has made such prodigious strides within the last few years, as to give a new composition, as it were, of the crust of the globe, from what was previously laid down, up to even the time of Sir H. Davy. Three earths were then considered the only ingredients necessary to be determined as to their quantity, in considering the fertility of a soil. We now know that there are, on an average, fifteen or sixteen elements in most soils, some of which, though they exist in minute quantity, yet are of absolute necessity for the growth of certain crops.

Numerous works have, from time to time, appeared, having for their object the exposition of this constantly enlarging subject, yet it has appeared to me that there was yet a deficiency in the application of those discoveries and practices carried on elsewhere, to the cultivation of the soils of Ireland; this deficiency, it is hoped, this treatise will supply; and the author trusts, that this, the first application of practical chemistry to the agriculture of Ireland, will merit the favour of the intelligent farmer.

In order that any branch of industry be carried on successfully, it is of importance that there should be a thorough knowledge both of the materials to be worked on, and the agents by which they are to be worked; in other words, it is as necessary for the farmer to know the composition of his soil, as the nature of his manure, or the necessities of his crop; but in this country little is known of the composition of Irish soils; and the author flatters himself that the chapter on soils will be found to contain some important and novel additions to our existing knowledge on that subject. Great pains have been taken to collect specimens of soils from the different geologic districts of the country, and to subject them to rigid chemical analysis, and the results suggest some remarkable reflections. Thus, if any one compare the analyses here given with those of England and Scotland (the only chemical examinations of soils which the Irish farmer has been hitherto acquainted with, he will, at once, perceive the caution he should display in adopting any suggestions for the amelioration of his ground, founded on such opposite data; that there are peculiarities of climate and soil connected with this country, which require to be studied before implicit faith be bestowed on recommendations derived from a consideration of the climate and soil of England and Scotland. For if we inquire about the limestone districts of England, we find that they bear a poor and scanty herbage, and hardly pay the trouble of being well worked; compare that with the limestone soil of Ireland, which, whether regarded as to its extent or its capabilities, deserves the designation of *the soil* of this island, which, instead of being barren, shallow, and mostly elevated, is chiefly a level plain, of immense depth in many places, and of an enormous fertility.

Again, when we contrast the greater humidity of this island, and the much greater yearly fall of rain, we must be struck with the opinion, that manures must bear a very different value, considered as a supplement to soils. It is a known fact, that guano in Ireland does not produce that amazing increase, which it is known to do in Great Britain; so that the person calculating on deriving from its use a benefit equal to that obtained in the sister island, will suffer a disappointment.

Lastly, when the superior agricultural fertility of this country is taken into consideration, such a circumstance should serve as a stimulus to adopt all the means, mechanical and chemical, which the present state of science furnishes; which means, it has been ascertained, have been able to raise land from the value of five to fifty shillings per acre elsewhere; and if such were applied to some of our naturally highly fertile localities, the amount of increase of produce would astonish even the most sanguine mind.

The author is indebted for much that is valuable in this work to the labours of others; and as he has not acknowledged the writers in the body of the work, he takes that opportunity here. Among those writings he has borrowed from are "Boussingault's Rural Economy," Schuler, Sprengel, Davy, Liebig, and Johnson's works on agricultural chemistry, the geological papers of Mr. Griffith, and Dr. Kane's valuable manual, the "Industrial Resources of Ireland." There may be others not acknowledged; "but as their doctrines are current, and the authors well known, they may be almost considered the property of all enlightened minds."

As it has been the author's intention to confine the following pages to the subject of chemistry in its application to agriculture, he has only slightly touched upon other important branches of science, necessary to a correct understanding of farming. This has been the case with the department of the physical improvement of the soil; as, draining, subsoiling, ploughing, and irrigation. This, in itself, is so important a subject, as to require a treatise for its own development.

In thus confining his subject, he does not wish to be understood, that the following out of chemical principles will lead to the most successful improvement in agriculture, or that chemistry alone is the "one thing needful." It must be acknowledged that there are many other elements absolutely necessary, such as a general industrial education, so well insisted on by Dr. Kane in the work quoted; an increased exertion in the upper class of landholders; an extensive diffusion of agricultural knowledge, by means of the formation of farmers' societies, and by free public lectures delivered under the authority of an agricultural scientific institution; some steady adjustment of the regulations respecting corn; and lastly, some social amelioration of the distressed agricultural population of this country.

INTRODUCTION.

THE science of Agricultural Chemistry consists of an exposition of the phenomena of vegetable growth; of the manner in which they secrete their nourishment; of the nature of that nourishment, and the changes which it undergoes; of the constitution of soils; of the nature of manures, and the manner in which land is rendered fertile by the different systems of raising crops off it.

It is hardly possible to study these questions properly without being in some degree acquainted with the laws of chemistry, or some account of the constitution and properties of the different substances which enter into the composition of either the crop or the soil.

The number of compound substances with which chemists are acquainted is very great: they may, with certain precautions, be resolved into fifty-six bodies; which, as they have resisted all attempts to alter their form, have been termed simple substances.

These simple or elementary bodies are conveniently divided into gaseous bodies, alkalies, earths, and metals.

Among the first-mentioned bodies are comprehended all those which are termed organic, whether animal or vegetable, and the three last include the inorganic substances.

The gaseous substances are four in number, oxygen, hydrogen, and nitrogen or azote.

Oxygen may be obtained, and its properties studied, by heating oil of vitriol upon black oxide of manganese in a glass retort; or by heating chlorate of potass alone an elastic air is given off, which is found to have very different properties from the atmospheric air. It is capable of supporting flame with great intensity; and a half-lighted taper burns when immersed in it, with great rapidity and brilliancy, until the whole of the oxygen in the vessel is consumed; if a living animal be introduced into a vessel its respiration and circulation is carried on with fearful rapidity, and the animal dies in a short time from over excitement and exhaustion. This gas is colourless and somewhat heavier than common air. It enters largely into the composition of air, forming one-fifth of its bulk, or four-fifths of its weight. It is that constituent of the atmosphere which supports living beings, and carries on combustion. If, instead of using manganese, we dilute the oil of vitriol with water, and add some iron filings, heat will be given out, and bubbles of air will be seen to rise through the liquor: these bubbles are hydrogen gas. It is exceedingly light, and is inflammable, so that if a tube be connected with the vessel in which it is generated, the gas issuing from the end may be inflamed, and will burn like a candle. If a taper be immersed in the vessel in which it is generated it will be immediately extinguished, shewing, that although hydrogen gas is inflammable, it does not enable respiration or combustion to be carried on.

If a piece of phosphorus be burned in a jar of atmospheric air confined over a vessel of water, after the white clouds have settled down, the water will be found to have risen about one-fourth of the height, and the air contained in the jar will be found to have acquired very different properties,—a taper can no longer burn in it; it is not fit to support breathing; it has properties very different from oxygen; it is, in fact, the residual portion of the air deprived of its oxygen, it is nitrogen gas.

There is another substance which enters into the composition of organic bodies which is not a gas, this is *carbon*, the pure inflammable part of charcoal.

When wood is burned in a heap closely covered up, it is converted into a light, porous substance; when coal is burned without free access of air it is converted into coke. Plumbago, graphite, or black-lead, are other forms of carbon. The diamond is the purest known form of charcoal. However they may differ in appearance, charcoal, coke, plumbago, and the diamond, are essentially the same body, *carbon;*

they all have the property of burning away in air or oxygen gas, forming by their burning a gas called carbonic acid, which is composed of the oxygen of the air united with a portion of the carbon.

These three gases, oxygen, hydrogen, and nitrogen, with solid carbon, go to form organic substances, such as the tissues and cells of animals and vegetables; and various as the forms of organism are, they differ only in the proportion, and not in the elements themselves.

The alkaline substances occurring in the vegetable or animal world are three, *potash*, *soda*, and *ammonia*. These bodies have properties in common, such as that of deepening vegetable colours generally, and of altering some; of uniting with acids, neutralizing their properties, and forming salts; and of uniting with oils to form soaps.

Ammonia differs from the other two in being driven off from its combinations, and of being decomposed by heat, and hence obtained the name of Volatile Alkali; it is a compound of hydrogen and nitrogen, and is a main element in the composition and nourishment of animals and plants. The other two are composed of metals united with oxygen gas.

By boiling the common pearl-ash of the shops with fresh slacked lime, a solution of potash is obtained; by boiling the soda of the shops with quicklime the pure soda is obtained. The object of using the lime is to separate the carbonic acid with which the alkalies were previously united.

The earthy bodies are, lime, magnesia, alumina, and silica. These, like the two alkalies, have a metallic base united with oxygen gas.

Lime is an extensively diffused body, generally found as a carbonate, that is combined with carbonic acid, which can be drawn off by heating.

Magnesia is a more rare production, also existing as a carbonate; the carbonic acid can be separated in the same way as with lime.

Alumina is the basis of porcelain and pipe-clay, and of alum; it may be obtained from the latter salt, by adding to its solution an alkali, when a white powder, alumina, will fall.

Silica, or the earth of flints, quartz, and sandstone, is a well known body.

Of these four earths, silica and lime are more commonly found in plants than the rest; alumina does not exist even in the smallest proportion; they are dissolved from the ashes of plants, by means of acid, with the exception of silica.

The metallic substances found in soils or plants may, as far as agricultural interest is concerned, be confined to two, iron and manganese.

These are found always united with oxygen, forming oxides of iron and magnesia, to which are sometimes superadded acids, either mineral or organic, forming salts of these metals.

Iron unites with oxygen in two proportions, with a small proportion forming a *protoxide*, and with a larger proportion forming a peroxide. The same occurs with manganese. They may be detected in the ashes of plants, by incineration, when if a red or brownish appearance is seen, oxide of iron is present; if blackish or purple, oxide of manganese exists. The colour of sandstone rock, and soils, is due to peroxide of iron.

Sulphur and phosphorus, when united with oxygen, form acids, which are constant ingredients in plants and soils.

Sulphuric Acid, when combined with lime, exists in clover and a few other plants. Free sulphur is occasionally found in plants. *Phosphoric Acid*, combined with lime, forms bone earths, and with magnesia, it is constituent of wheat and most corn crops.

Chlorine is a gas of suffocating smell, and forms a large proportion of the spirits of salt (muriatic acid). It also combines with the base of the soda, and forms chloride of sodium, or common salt.

Such are the substances which enter into the composition of plants or of soils; and the greater number of these ingredients a soil contains, generally speaking, the more fertile it will be; and for this reason, that as all plants require them for their healthy growth, and cannot obtain them except from the soil, it is manifest, that in order for the plant to grow healthily, the soil must contain these elements.

A MANUAL,

&c. &c.

CHAPTER I.

OF VEGETATION—ITS PHYSIOLOGICAL AND CHEMICAL CHANGES.

A VEGETABLE is a substance, or combination of organs endowed with life, or the capability of sustaining its existence, and propagating its species. It is incapable of moving from place to place, and is not endowed with perception.

The parts of which plants are made up are called organs; and may be either those of nutrition, or those of reproduction.

The organs of nutrition are the root, the stem, the branches and leaves. These perform the office of sustaining the growth, and supporting the life of the individual plant.

The organs of reproduction are: the flower, and the fruit, or seed. These have the property of raising up new plants, and thus continuing the species of the plant.

The root is the continuation of the stem underground, where it divides into numerous, minute, hairy rootlets, termed *radicles*, each of which may be looked upon as a simple hollow tube, closed at its farther extremity. This extremity of the radicle is covered over with a thin membrane, through which, like as fluids are soaked through a sponge, the liquid nutriment is conveyed into the body of the root, and thence upward.

The stem is the over-ground continuation of the root upwards—is of a symmetrical form; and when cut across, in most of plants and trees, presents a regular disposition of parts. Pith is found occupying the central portion of the stem; round which woody fibre is disposed in concentric rings; and the whole enclosed by the layers of bark, coated with the epidermis or pellicle. The pith consists of minute bladders, filled with a pulpy fluid, laid horizontally over each other.

The woody fibre consists of tubes laid vertically by the side of each other, generally hollow, or rolled in a spiral form, so as to enclose a space, and capable of conveying up into the leaves the liquid drawn from the soil, and of returning the sap downwards. The branches have the same structure and office as the stem.

The leaf arises from the branch by a little bud, and contains all the parts which make up the stem; thus the woody fibre, with the pith, runs along the middle of the leaf, forming its midrib, and spreading its net-work over the whole upper surface; doubling round the edge, it runs coalescing, and forming a regular system of tubes, which run along the leaf-stalk into the inner layer of bark: the meshes of the net-work of veins is filled by a green, pulpy matter, formed into cells; and the whole is covered by a thin membrane termed epidermis.

The fluid absorbed by the root of the plant is water, holding some carbonic acid in solution, and some salts derived from the soil; it traverses the stem, where it dissolves some vegetable matter, and passes through the branches into the leaves: this fluid is the sap. In the leaf it undergoes very important changes, and, passing along its under surface, descends into the inner layers of bark and forms the proper juices of the tree, of which the last year's layer of white wood and bark is always full.

When a shoot with fresh leaves on it is placed in a vessel of common water, in a short time bubbles of air are given off from the surface of the leaves when the vessel is exposed to the sun: this does not take place if the vessel of water be previously boiled. From this fact, Bonnet concluded that the gas was derived from the water, and Priestly demonstrated it to be oxygen gas.

When exposed to the sun's rays leaves give off oxygen gas, while in the dark, and during the night, they vitiate the air, and render it unfit for respiration and combustion. The oxygen gas thus obtained, is derived from the decomposition of carbonic acid which the water contained: the carbon being retained by the plant, and the oxygen of the carbonic acid liberated.

Thus we perceive that processes the reverse of each other go on in plants during the day and during the night: in sun-light carbonic acid is absorbed, and oxygen liberated; in night-time oxygen is absorbed, and carbonic acid liberated.

The deposition of carbon then, in a plant, goes on in the day-time, and depends on the quantity of sun-light. Hence, in long summer days and tropical countries, more carbon or woody fibre is formed; while in the dark, and in wintry climates very little carbon is deposited, and the plant is thin, watery, and palish.

Oxygen gas is necessary for the roots of plants : the air which occupies the interstices of vegetal earth contains a large proportion of oxygen—it is, in fact, necessary for their life, and if they cannot obtain it they speedily perish : hence the soil around roots must be thin, capable of being moved about, and permeated,—hence, also, if roots be immersed in stagnant water they perish, while they live much longer in running streams.

Roots then convey two kinds of nutriment : water holding carbonic acid in solution, and water having oxygen gas in solution, this latter in passing up the vessels in the stem, derives from all parts not green, some carbon, by which means carbonic acid is formed. Both these solutions are carried up into the the leaves, where the carbonic acid is decomposed as described ; by this means carbon is being constantly transferred from the lower and older to the upper and younger parts of the plant. Carbonic acid, then, is supplied to the leaf by the two modes thus indicated ; but there is a third which is more extensive in its operation than either, and the one upon which the plant mainly depends for its formation of woody fibre—it is by the abstraction of the carbonic acid of the air ; this takes place in the small pores which exist on the upper surface of the leaves in most plants : the acid gas being decomposed on its entrance, the carbon fixed in the leaf, and the oxygen liberated. As the quantity of carbonic acid gas in the air is minute, not exceeding one part in a thousand of air, the more atmosphere in contact with a plant, the more carbon will be extracted ; hence, in windy weather, plants form more carbon than in a calm.

The nitrogen or azote of plants is derived almost wholly from the soil; it is usually presented to the plant in a state of combination, as ammonia, in which it is united to hydrogen; the ammonia dissolved by the moisture of the soil is absorbed by the plant.

Manures are the chief and, in some cases, the only source of azote to vegetation. The fact that cereal plants, grown under the influence of highly azotized manures, contain more nitrogen (in their gluten), seems to nearly prove this: it is right, however, to observe, that there are a few plants which derive their nitrogen from the air, and important use is made of this in the system of rotation.

From the fact of plants drawing a portion of their nourishment from the soil, it is evident, that if plants be continually cultivated off the same spot, the soil must become exhausted of certain of its contents. The experiments of M. Boussingault shew .

1st. That clover and pease, cultivated in a soil quite destitute of manure, acquired, independent of carbon, hydrogen, and oxygen, an appreciable quantity of azote.

2nd. That wheat and oats, cultivated under like conditions, likewise gained carbon, hydrogen, and oxygen; but no appreciable quantity of nitrogen beyond what was contained in the seed.

The way in which nitrogen is assimilated by plants, is yet a matter of doubt, as it is one of the constituents of the air it might be directly dissolved in water, and drawn up by the radicles, or it might be obtained from the small quantity of ammoniacal gas (which exists constantly in the atmosphere), being dissolved by rain-water, carried down, and thence elaborated by the plant. Another source is in the nitric acid formed in the atmosphere during thunder storms; this acid being then absorbed by the earth, supplies its nitrogen to the plant: it is a known fact, that after a thunder-storm, plants thrive better.

Another probable cause is—one to the study of which M. Becquerel has devoted himself—certain electric influences by which hydrogen, in the nascent state, coming into contact with nitrogen, forms ammonia. Aware of this fact, we can understand how organic matters, not containing any nitrogen when putrescent, coming into contact with the atmosphere rob it of some of its nitrogen, and can give rise to ammoniacal salts, which will act as a fertilizer to the soil.

In the growing plant, a portion of the water absorbed by the roots becomes fixed in the composition of the vegetable, and necessary to it, and hence may be called its water of constitution; and by uniting with the carbon of the plant, goes to form some of the proximate principles of vegetables which may be said to be composed of carbon and water: such are gum, sugar, starch, woody fibre, &c. In other principles besides the carbon and water, there is an excessive quantity of hydrogen above what is necessary to form water, and those bodies have generally mild properties, and are called resins, carburets of hydrogen, and fat oils.

When a plant is burned in the air, a quantity of ash is left behind. Every part of a vegetable yields ash, but it differs in amount and kind; equal weights of herbaceous plants leave more ash than woody trees; in these the youngest shoots, and those parts which contain most sap, yield most ash: the trunks give more than the branches, and these last than the leaves.

These ashes are usually composed of potash and soda united to chlorine and acids; earthy and metallic phosphates, lime, and magnesia, generally, as carbonates, silica, oxides of iron, and manganese: occasionally a few other matters are present, but they are rare.

These substances are to be found in the soil on which the plants are grown, and are, in most cases, derived from it. Where a manure is added to supply certain salts, these will be found in the plant.

The ashes contained in plants are in weight very small in proportion to the rest of the plants; thus in dried wheaten straw, in 1000 parts, there were only 70 parts of ash; and in dried ear of same, only 24 parts. Potatoes gave only 45; turnips 76, and hay 90 parts in a 1000 of the dried plants.

Berthier has remarked, that alumina (clay) is not usually found in the ash of plants, though it is to be found in the soil on which it grows; and this he attributed to the fact that alumina, not beingeasily soluble or uniting readily with acids, cannot enter the absorbent vessels of the roots. It has been found in a few plants, butit is supposed to have been introduced by accident.

Silica is rarely found in the ash of trees, but is plentiful in annuals, biennials, and the corn crops; the grasses have their epidermis coated with this element, in some cases to an extent to strike fire with steel.

The matters which form the ash do not exist in the same state of combination in the plant in which they are found after being burned. Thus the mineral bases are generally united to acids of vegetable origin, which are destroyed by the incineration and converted into carbonic acid. The phosphates, sulphates, and clorides, being able to resist the fire, escape unchanged, while the tartaric, malic, citric, and acetic acids, are decomposed and converted into carbonic acid.

These salts must all have entered the rootlets in a soluble state, the spongioles being too fine to admit *any* solid body; carbonate and phosphate of lime or magnesia are not soluble in common water, but water holding carbonic acid in solution has the property of dissolving both the carbonate of lime and magnesia, and thus they are carried into the plant. The phosphates may, by uniting with potash or soda, form double salts, as phosphate of potass and lime, phosphate of magnesia and lime, and thus enter the plant more readily, but this last is only an opinion.

These salts are presented in very small portions *at a* time to the rootlets: and even though it might be of great utility to the health of the plant, yet if any salt be *presented* in a strong solution, the plant will be decidedly injured by it.

Saussure looked upon the salts contained in plants, as being accidently derived from the soil, and not necessary to the life of the plant; but it is a known fact, that annual plants, placed in a soil deprived of the usual salts, although they grow, yet never have the same vigour as when the salts are present. Marine plants languish where they cannot obtain sea salt, and wheat (though the straw will rise) will not fill the ear unless it can obtain the phosphates.

The following are tables of the ashes yielded by different plants, and by the different parts of the same plant.

	Potatoes.	Turnips.	Clover.
Silica	5·6	6·4	5·3
Alumina and Oxide Iron	0·5	1·2	0·3
Soda	Trace	4·1	0·5
Potass	51·5	33.9	26·6
Lime	1·8	10·9	24·6
Magnesia	5·4	4·3	6·3
Chlorine	2·7	2·9	2·6
Carbonic Acid	13·4	14·0	25·0
Sulphuric Acid	7·1	10·9	2·5
Phosphoric Acid	11·3	6·1	6·3
Coal, Moisture, and Loss	0·1	5·5	0·0
	100·0	100·0	100·0

	Wheat.	W. Straw.	Oats.	O. Straw.
Silica	1·3	67·6	53·3	40·0
Alumina Oxide Iron	,,	1·0	1·3	2·1
Soda	,,	0·3	,,	4·4
Potass	29·5	9·2	12·9	24·5
Lime	2·9	8·5	3·7	8·3
Magnessia	15·9	5·1	7·7	2·8
Clorine	,,	0·6	0·5	4·7
Carbonic Acid	,,	,,	1·7	3·2
Sulphuric ,,	1·0	1·0	1·0	4·1
Phosphoric ,,	47·0	3·1	14·9	3·0
Water and Loss	2·4	3·7	3·0	2·9
	100·0	100·0	100·0	100·0

	Saintfoin.	Pease.	Rye Grain.	Rye Straw.
Potash	6·75	39·51	31·89	17·03
Soda	20·33	3·98	4·33	,,
Lime	,,	5·91	2·84	8·98
Magnesia . . .	8·57	6·43	9·86	2·39
Peroxide Iron .	,,	1·05	0·80	1·35
Phosphate Lime .	54·89	34·50	46·03	3·80
Sulphate Lime .	2·87	,,	,,	,,
Sulphuric Acid .	,,	4·91	1·42	0·81
Chloride Sodium .	2·18	3·71	trace	,,
——— Potassium	,,	,,	,,	0·25
Silica	1·10	,,	0·17	63·88
Phosphate Iron Carbon and Sand	3·31	,,	2·66	·99
	100·00	100·00	100·00	100·00

The flowers of vegetables perform an important office in the life of the plant: namely, the formation of fruit and seed, whereby the life of the species is continued. It is from the seed the future plant rises; and this is accomplished by the aid of the atmosphere, water, and certain organic substances spread over the soil.

When a seed is moistened, exposed to air, and to a temperature not below 45 degrees, it begins to germinate; that is, it sends a radicle downward to be a root, and a plumule upwards to be a stem. This is what occurs to the seed after it is planted.

In this process, the oxygen of the air is abstracted, and a certain quantity of carbonic acid is produced; the volume of the latter representing a like volume of oxygen. Germination, with its consequent formation of carbonic acid, takes place equally well in oxygen; but it will not proceed in a gas which does not contain oxygen. Hence it is from its containing oxygen, that air acts so favourably in the process of germinating. Besides carbonic acid, another acid of vegetable origin is formed in the grain during this process, which was formerly believed to be acetic acid; but is now known as lactic acid; also, the starch which the grain possessed is converted into sugar by this exposure to heat and moist air.

From this process of germination we can understand how necessary it is that there should be free access of air to seed newly planted; and how it is impossible for seed to vegetate in lands which are tenacious, wet, and cold.

Humboldt has shewn that chlorine gas possesses remarkable properties in aiding germination, especially in old seeds. When watered with a weak solution, he made plants to germinate, which died when watered with ordinary water. By this means seeds of many years old might, with advantage, be kept alive during early life, and, even with young seeds, it might cause a greater number to germinate. The solution is cheaply made, and should be used very dilute.

The seeds contain, besides starch, a substance termed gluten, which contains a small proportion of nitrogen in its composition, and is a highly nutritious substance; in proportion to the quantity of gluten found in flour, so is it valuable as food. In the germinating plant, its office is to supply the necessary proportion of nitrogen, which, in the full-grown plant, is derived from the air; it likewise affords heat to the young plant by its decomposition; this glutinous matter contains besides true gluten, vegetable albumen, fibrin, and casein.

Plants derive the carbon, hydrogen, oxygen, and nitrogen, which form their structure, from their food being partly absorbed by the roots and partly by the pores of the leaves; of these substances, oxygen gas is the only one which can be said to enter the plant in a free state, that is, absorbed directly from the air. The hydrogen generally enters the plant combined with oxygen, as in water. The nitrogen, though entering largely into the constitution of the atmosphere, rarely enters the plant in an uncombined, but is almost always absorbed, either combined with hydrogen, as in ammonia, or with oxygen, as in nitric acid. Carbon, being a solid substance, cannot enter plants in that state; it must enter into some chemical combination, whereby it is rendered soluble and capable of being absorbed through the membrane covering the rootlets; when combined with oxygen, it forms carbonic acid, which, both as a gas and in solution in water, is capable of entering both the leaves and roots of plants; and it is by means of carbonic acid that most of the woody fibre of plants is formed; besides it, there are two other acids, the humic and the ulmic acids, which supply carbon to the rootlets only. These three acids deserve a short description.

Where any strong acid, as the *muriatic*, is poured upon limestone, chalk, or marl, effervescence occurs, or, in other words, bubbles of air are abundantly given off, which, if the vessel be deep, will collect and fill it up, and even run over the edges; this air, or gas, is carbonic acid, which has been released from the substance, owing to the superior affinity of the stronger acid. This carbonic acid is destitute of colour, taste, or smell; but it cannot support animal life or a burning body; hence, a lighted candle plunged in it is immediately extinguished, and an animal is suffocated. It is the same gas which collects in brewers' vats during the fermentation of malt; it is produced largely by the breathing of animals, while any substance is being burned; by decaying animal and vegetable matter; and in the fermenting of dung and compost heaps, which owe much of their benefit to the evolution of this acid. It is composed of one proportion of carbon united to two proportions of oxygen, or in 1000 parts of

Carbon	273
Oxygen	727
	1000

The humic and ulmic acids are derived from the decomposition of the vegetable matter. They both contain a quantity of carbon, and are soluble to some extent, and, consequently, can supply the plant with carbon; but they are neither so abundant nor so readily soluble as the carbonic acid.

If some turf be boiled with carbonate soda, a liquid of a deep colour is obtained; if spirit of salt be added to this, flocks of brown powder fall, which is humic acid; if, instead of soda, ammonia be used, *ulmic* acid is obtained by the same process.

CHAPTER II.

ON SOILS.

The surface of our planet, the earth, does not consist of a simple elementary substance, as the ancients imagined. It presents many different physical features, and its chemical composition varies in many localities. The earth arises, in most instances, from the disintegration and decomposition of the surface rock of the district.

Rocks are divisible into 1. crystalline, which date their origin from the first ages of the world; their elements being mixed together by fusion, according to the laws of affinity, constitute certain minerals with which we are acquainted; such as quartz and felspar, mica slate.

2. Sedimentary rocks. These do not vary less in their composition; the same causes which tore asunder the crystalline or igneous rocks, removed many of their elements before their reunion in this second form: thus grains of quartz are common in these rocks, mixed with mica; but rarely is felspar to be seen. Such is the case with greywacke, the most ancient of the sedimentary rocks. The calcareous rocks, situate lowest down in this formation, are hard, compact, and clayey, forming limestone, while the upper, or more recent beds, are more friable, being the calcareous gravel and chalk.

The sedimentary or stratified rocks were originally deposited in horizontal beds by the action of water; but, in many cases, this position has been altered by subsequent convulsions of our planet; the rocks generally situate undermost being protruded upwards, and, in many cases, appearing between and above those of most recent formation. Such is the cause of formation of mountains, which, in many cases, are composed of crystalline rocks which have been forced upwards.

The organic remains found in stratified rocks shew, that their formation is of a much later occurrence than the crystalline rocks, having been formed when vegetables and animals lived on the surface; and the limestone formation, especially the upper or chalk beds, are so full of remains of animal life, that it is questionable if they were not formed altogether of the skeletons of minute animals; indeed, lime only begins to appear in what are called the secondary formations, and gradually increases in amount in the most recent of the tertiary beds; magnesia, again, is only found in small quantities in primary and secondary rocks, while it is a characteristic ingredient of tertiary beds. The more dense bodies, as metallic oxides, are confined to the primary or the earliest deposit of the secondary strata. The stratified rocks derive their origin from the disaggregation of the crystalline rocks, which has been produced by the combined action of water and the atmosphere. Water penetrating into the chinks and pores of rocks remains in the fissures. When the temperature falls, the water freezes; it expands and breaks the rock in pieces. During frost, the pieces are cemented together; but when the thaw comes the currents of water carry down the fragments to the bottom of the valley, and the continual rubbing they receive reduces them ultimately to the state of fine sand.

Rivers and streams carry down a considerable quantity of earthy matters, and deposit them at their mouth; or they overflow their banks on the neighbouring ground. These are called fluvial deposits; and, in some cases, the arable soil is formed by it: in others, it is greatly improved.

The quantity of clayey matters carried down by large rivers is enormous. The waters of the ocean are muddied by the River Amazon 300 miles from its mouth. The delta of the Ganges has a base of 200 miles; and the whole triangular space comprizes above 20,000 square miles, which has been formed by deposition from the river and its tributaries; and yet the whole mud carried down by the river is not deposited, for the sea is muddy at sixty miles from its mouth. The quantity estimated to be brought down in the rainy season has been, according to Major Remell, as much as 450 millions of tons daily. At the mouth of the Elbe, little banks thus formed are called *polders*, and are cultivated very richly by the Hollanders.

According to Mr. Horner's observations on the waters of the Rhine, it is probable that nearly 400 tons of solid matter are carried down daily; and we know what effects that quantity has produced in the lapse of ages—even the formation of Holland.

The matters carried down are highly fertilizing, and contain all the ingredients necessary for ensuring good crops. The mud deposited by the overflowing of the Nile serves as manure to the Egyptians; and its composition has very lately been determined by Lassaigne, viz.:

Silica	42·50
Alumina	24·25
Peroxide Iron	13·65
Carbonate Lime	3·85
——— Magnesia	1·20
Magnesia	1·05
Ulmic acid and organic azotized matter	2·80
Water	10·70
	100·00

Its value as a manure depends chiefly on the ulmic acid and the azotized matter.

Exceedingly analogous is the composition of alluvial deposit from Wexford, which, by my analysis, furnished in 100 parts:

Quartz grains, siliceous sand combined with lime and iron as silicates	57·0
Alumina and peroxide iron	4·0
Protoxides of iron and manganese	2·6
Carbonate of lime	7·3
Magnesia	1·5
Phosphoric acid combined with iron	trace
Sulphuric acid in gypsum	3·3
Chlorine in common salt	2·7
Potash	3·4
Soda	1·8
Organic matter soluble	2·0
——— insoluble, and water	14·0
	100·00

This deposit, when spread as manure, would be a valuable fertilizer on wheat fields.

The crystalline rocks are destroyed by chemical actions arising from atmospheric causes. Thus, in minerals containing iron, it passing to the state of peroxide attracts both oxygen and water, and tends to break up the rock in pieces. In some rocks this takes place more readily than in others, for some granites are more easily destroyed than others. Clay-slate, from its structure, is little able to resist the decomposing agents. Limestone resists better, but is ultimately attacked by the water which dissolves it. Graywacke resists still longer(*a*).

The sedimentary rocks bear evidence of having been submitted to the action of sea water, as they contain a quantity of the salts, such as exist in the ocean, and which are among the most valuable substances which could be yielded to plants. The soil arising from the sedimentary rocks, in the majority of instances, are the most valuable in an agricultural point of view.

A soil is made up of many substances, and in proportion as one substance predominates above the rest, so the soil acquires a distinctive appellation; thus, in a mixture of loam and sand, if the former be in excess, it would be termed a loamy sand; if the latter, a sandy loam. Some of the ingredients, though found in all vegetables, and therefore presumed to be necessary to their existence, are yet in so small a quantity as to leave a soil to be composed of a large proportion of two or three ingredients. These, which really form the basis of all cultivated grounds, are sand, clay, and carbonate of lime.

(*a*) These causes, conjoined with some physical ones, as changes of temperature, combine to reduce the most solid rock to a fine sand or clay, which is washed down the mountain side, and forms the fertile plains beneath. Such is the mode in which soils are generally formed.

Sand (or powdered quartz) is abundantly found in nature in the mineral rock crystal, all sands, whether fine or coarse; sometimes as massy rocks or mountains among the primary or igneous rocks. Thus, the Sugarloaf hills in Wicklow, Nephin in Mayo, and Binabola in Connemara, are masses of quartz. It is the silica of chemists—the oxide of a metal called silicium. It is, when pure, white, gritty, and its weight may be 27, water being 10.

As it exists in sand, it is insoluble in water; but alkalies render it soluble. It exists desolved in some warm springs, and in the Artesian wells of the Seine. The rock crystal may be considered its purest form. The quartz sand of the County Donegal is white, and perfectly pure silica; but as sand is usually obtained, its composition is thus:

Silica	90
Oxide of iron	9
Water	1
	100

The colour being contributed by the oxide of iron.

Clay or argil is derived from the decomposition of felspar rocks, the potash of which has been previously washed away. When pure, it is white and unctuous, and adheres to the tongue or moist surfaces, and has a peculiar odour; it absorbs water rapidly. When mixed with any quantity, it forms a paste, which contracts when dying, by parting with the superabundant water. Hence, clayey lands, in very dry weather, form fissures and large crevices in the ground. Its weight is about 2·5. It usually contains, mixed up with it, sand, oxides of metals, pyrites, carbonate of lime, magnesia, and combustible coaly substances.

Clay, when pure, such as porcelain clay or kaolin, is met with in Wicklow, Down, and Tipperary, and is a strictly chemical compound, being composed of

Silica	47·0
Alumina	39·2
Water	13·8
	100·0

It retains the water with great energy.

Carbonate of lime (limestone) belongs to all the geologic formations. It occupies a great part of the surface of Ireland, being its chief rock. When pure, it consists of

Lime	56·3
Carbonic acid	43·7
	100·0

Its specific gravity being from 2·7 to 2·9.

When thrown into spirits of salt it disappears completely, with effervescence. When heated, it parts with its carbonic acid, and is then called quicklime. It dissolves to a very small amount in cold water. When exposed to air, quicklime unites with a small quantity of water, forming a hydrate of lime, and gives out much heat in so doing. This is called slacking. When water holds carbonic acid in solution, it then dissolves lime with great facility. When the water parts with the carbonic acid, the lime is deposited. It is in this way that tufas and stalactites are formed in limestone soils and caves; it is in this state it enters the vessels of plants; for all water running on the surface of the earth contains carbonic acid.

These substances, when separate, form a sterile soil, but when mixed together fertility is insured, which depends as much on the chemical, as on the physical properties of the mixture.

In proportion as a soil contains much clay, it absorbs moisture freely, it resists drought, and retains energetically the water necessary for the growth of plants. Manures act well on these grounds even in the dryest seasons; but in very wet seasons, the soilis completely drenched; on the contrary, in hot seasons it sinks and hardens, so that rootlets can, with difficulty, penetrate it. Intense cold also acts disadvantageously on it.

In sandy soils, excessive moisture rarely occurs, but droughts are injurious; crops are easily and cheaply raised, but manures never benefit to the same extent as in clayey lands, because the rain-water dissolves them and carries them out of the porous soil.

An argillaceous soil, properly so called, contains 40 per cent. of sand; with less sand it is too tenacious to be worked without enormous expense. If it contains humus, it is a good wheat soil; if the sand be less, barley is grown better on it; with a still smaller quantity of sand, it is fit for oats. Such a soil is not exhausted by constant cropping, as happens when there is more sand, and if it contain from 40 to 50 per cent. of sand, it does not stiffen and harden like the more clayey soils. It is also adapted for clover, potatoes, turnips, tobacco, colza, and flax. Where soils contain from 60 to 80 per cent. of sand, the cultivation of wheat is doubtful; where it is above 70, it is hardly justifiable, as the crop seldom succeeds, except in rare circumstances; but it is fit for barley, and in such land, rye is more successful. It is a soil easily worked, requires to be manured often, and in small quantities at a time.

Land with 75 per cent. of sand will grow oats; it will yield crops even when there is 85 per cent. of sand, but weeds rise so rapidly, as to be a continued annoyance, which is best remedied by turning it into meadow; after 85 per cent. it will no longer grow oats, but rye or buckwheat will succeed. When a soil contains above 90 per cent. of sand, it is of little agricultural value. In dry seasons it is as moveable as the sand on the sea shore.

When we wish to estimate the value of a soil, an important element to consider is, its thickness. In trenching a field, at first sight the thickness of the vegetable soil may be determined from the humus it contains, as it is darker coloured than the soil which underlies it. Its thickness is variable, from one inch upwards. In America, where in some districts the soil has been never worked, it is many feet deep. The deeper it is, the better for culture, for it suffers less from heats and cold.

The subsoil is the bed underneath that just described. In mountainous countries it is frequently of the same constitution as the rock on which it reposes. It is occasionally only a few inches thick; more generally some feet deep, and on level ground, still more. On the north side of Dublin, the subsoil is in some places five or six yards deep.

On hilly grounds, the soil and subsoil are of the same chemical composition as that of the rock below; but in extensive levels, the subsoil may be widely different from the surface; in this case the subsoil has the constitution of the rock below, while the surface may have been formed by a deposit from a body of water which conveyed its earthy matters from a distance; in this case of alluvial deposit forming the soil, it may possess very different and even opposite properties from the subsoil. Such is the case in many of the limestone districts of Ireland; the rock below being of the mountain limestone type, while the surface will only contain between 1 and 3 per cent. of carbonate of lime. Where the upper and subsoil differ thus in composition, the latter may be used as a manure to the former, to supply any deficiencies.

Another important point of consideration is, the climate of the country and the aspect of the ground; generally speaking, argillaceous soils are more adapted for dry climates, and sandy soils for wet ones. There is no doubt that a sandy soil is fruitful in proportion to the amount of rain and its frequency. Kirwan has stated, that where the fall of rain is 26 inches yearly, the constitution of a fertile soil would be silica 56, alumina 14, and 30 of calcareous matter in 100 parts; and if the fall of rain be more, the quantity of silica should be greater; if the rain be less, the proportion of clay should be higher. This occurs in Ireland, where the average fall of rain is above 30 inches—according to Dr. Kane's computation, 36; and the proportion of silica found in most soils is increased in a corresponding ratio.

Could a constant supply of water be obtained by rain or irrigation, the question of the constitution of a soil loses its importance. The edges of rivers and streams are always fertile, no matter what the composition may be.

The less elevated, or the less inclined a sandy soil is, the more fertile will it be. The contrary holds good with argillaceous soils.

A soil which has a southern aspect is drier, warmer, and receives more light than any other.

It is easy, theoretically, to point out the deficiency of a soil and recommend the remedy, but in practice it may not be so, to apply it conveniently or at any reasonable expense. In such cases those plants must be chosen which are most adapted for such circumstances; hence the farmer should know both the qualities and defects of his land, by a careful examination, for otherwise he can form no estimate of the rent of his land, or the capital necessary to keep it in cultivation.

In this country the soils are mostly composed of the decomposition of the primary formations. The secondary formations, excepting limestone, are not abundant, and the tertiary formations, still rarer, as chalk, oolite, and new red sandstone. It is chiefly in the north of Ireland that the more recent formations occur, and generally speaking, on getting below the subsoil, the substances met with are either granite, limestone, or slate.

The primary, secondary, and tertiary, have very different agricultural capabilities, the latter being generally the most valuable, softer, and easier worked than the secondary; and containing a great variety in the number of its elements. In fact the number of ingredients present in a soil, determines its fertility. Hence where two geologic formations are exposed, the point of junction is always more fertile than either separately.

In taking account of the value of a soil, there are many circumstances to be considered beside the chemical constitution, such as the amount of fall of water, the inclination, the aspect, and the specific gravity of the proximate contents of a soil: thus, if we take a granite, or still better, a basaltic rock, we find it to be easily decomposable, from the lime and iron contained therein; the rock crumbles down and forms soil; constant rain and falls of water tend to bring those elements down to the plains, and in so doing they are deposited in the order of their gravity; the siliceous sand and the oxide of iron, being the heaviest, will be left on the sides of the rock, forming its sterile soil, while the lighter elements will be carried lower, and deposited in their successive order, first chalk, then alumina, and last, magnesia.

The granite districts in Ireland are very extensive, occupying the southern part of the County Down, appearing in Louth and Armagh, Monaghan, Cavan, and Leitrim, coated by hornblende and porphyry rocks on the north side, and chlorite slate and graywacke on the south; the felspar of this axis is red; it is found in Donegal, running east and west, at Erris and Connemara. The Dublin axis commences at Killiney, running south-west for nearly sixty miles; it differs from the Down or Mourne range, in containing no hornblende, and having the felspar white. Granite is composed of quartz, felspar, and mica. Quartz is composed almost entirely of silica, with impurities of not more than one per cent.; it is the main ingredient of all sands. I subjoin the constitution of the two last-mentioned:

Felspar.		Mica.	
Silica	65·2	——	46·1
Alumina	18·1	——	31·6
Potash	16·6	——	8·3
Iron	„	——	8·6
in 100 parts	99·9	in 100 parts	94·6

The following is the analysis of decomposed granite (freestone) obtained from Bohernabreena, on Dublin axis:

Silica	69·0
Alumina	15·0
Peroxide iron	5·2
Potash	8·8
Lime	·7
	98·7 in 100 parts.

From this analysis it would appear, that the minerals which enter into the structure of plants will be found, to a great extent, in granite soils; the potash, silica, and alumina being highly favourable to vegetable life; its deficiencies are lime and magnesia, which can be applied as manures, or are naturally added when it is contiguous to basalt. The striking contrast observed in granite districts, is due to the felspar which it contains, and in proportion as this ingredient is abundant, so will the value of the soil increase. The potash of the felspar appears to be the essential fertilizing agent, perhaps some little is due to the oxide of iron contained in the mica; but it should be remembered, that soils which are micaceous to a great extent are not fertile. Felspar, when mixed with quartz, forms a good soil, which, when manured with calcareous matter, sea shells, or lime, becomes most productive of wheat and barley. Indeed the value of felspar as manure is hardly rightly estimated; but when we remember that, according to Liebig, a cubic foot of felspar is sufficient to supply a wood covering nearly 27,000 square feet of surface with potash enough for five years, we may form some idea of what utility the common freestone or decomposed granite would be to some soils requiring it.

The fertility of granite soils is more affected by elevation than by composition; for in elevated places the consequent washing of the soil by rains, tends to remove every ingredient from it, except siliceous sand. The more elevated spots grow larch well, which requires only a thin soil, but the lower situated and deeper soils, which admit the use of the plough, require only to be limed to make them among the most fertile soils of the island.

The following conditions, then, are necessary to insure the fertility of granite;

1st. That it should be only of moderate elevation above the sea.

2ndly. That the felspar should be abundant, and easy of decomposition.

3rdly. The presence of oxide of iron, giving to the soil a brownish colour.

Basalt occurs columnar on the north coast of Antrim, in Pollardstown, Kilteely, and Linfield, county Limerick, and the neighbourhood of Arklow; it occurs amorphous over nearly the whole of Antrim and Derry, and boulders and detritus of same abound in Armagh, Tyrone, and Down. Trap extends over whole of Antrim and Derry, east of River Roe. In Limerick the trap area is of limited extent, occurring in patches. The hills of Pallas, Knockdirk, Knockruagh, and Cromwell, are of trap. Walls of trap also are found near basalt, and are called dykes; these have been found at Killala, Erris, and Donegal. There are also isolated hillocks of trap, appearing in the secondary district, and forming themselves into lines, such as the hill of Allen, in Kildare, Croghan Hill, King's County, and Knockkosthee, Westmeath, which are all peaks of trap.

Greenstone is that variety of rock where the crystals of felspar and hornblende are distinct, and may be either fine-grained or coarse; in the latter case, if it be red, it is called Sienite, which is found in Donegal: where the fine-grained variety contains large crystals of felspar, it is called greenstone porphyry. Greenstone occurs in a hill east of Hollywood, County Wicklow; it is also found flanking the granite axis of Wicklow. The Carlingford mountains are masses of greenstone.

The basalt and trap formations containing those different rocks, present a variety of soil according to the proportions in which they are found to be united, but in general their character is very fertile. They differ essentially from granite soils in the abundance of lime contained in the trap, which is often entirely absent in the granite. In some trap soils it exists in the proportion of one-ninth, and in others one-fortieth, varying between the two limits, the lowest of which is sufficient for the growth of any crops requiring it. The greenstone, from its composition, is highly favourable to the growth of the commonly cultivated crops, as no two minerals could, by their decomposition, supply more of the inorganic food of plants than these: a soil being formed porous to allow the access of air to the roots of plants, and the percolation of water, yet tenacious enough to retain moisture, and supply it to the plant when necessary. Most of the varieties of basalt are easily decomposed, from the potash, lime, and oxide of iron contained in them. The lime being, in basalt, incompletely saturated with carbonic acid, has a constant tendency to absorb an additional quantity of the latter: the iron also is in a state of minimum oxidation, and, when freely exposed to air, rapidly runs into the state of peroxide; so that in the formation of these soils from their rocks, carbonic acid and oxygen are being continually abstracted from the air. The soil so formed is of a reddish-brown colour, friable, and if well drained may be easily kept, by manure and good culture, in a state which would gradually increase its productiveness. The soil is rubbly, and produces large crops of wheat, barley, oats, turnips, and vetch. Soils formed from basalt, greywacke, and porphyry, are, *cæteris paribus*, the best for meadow land, on account of the quantity of potass entering into their composition.

On flat grounds trap soils are not fertile, owing to the accumulation of water, and production of bog and heath, which can only be remedied by draining.

The requisites for insuring fertility in trap soils are:

1. That it lie on an inclined plane and be well drained.
2. That it be of greenstone rock, of hornblende, or one in which lime is contained.

In the clay slate soils a great variety of composition exists; when mixed with greenstone it is fertile, when very shaly it is not. Clay slate occupies the east of Wicklow, Wexford entirely, east of Waterford, south of Cork, and is found in Tipperary; in the North, the greater part of Down, Armagh, Monaghan, and Cavan, where it merges into the graywacke bed.

The soil is in many cases of a thin character, formed of decomposed rock and organic matter; between this soil and the rock is found a layer of partly decomposed rock, grey, splintery pieces. The upper soil is mostly loose, free, and tender, and its value is in a great degree dependant on the position of the strata: if this be parallel to the horizon, it is retentive of moisture, and capable of being a remunerating soil; but if it be inclined or vertical, it carries the fine soil and manure down between the layers, and becomes a greedy soil; its elevated and mountainous character, in many parts, renders it in a degree unfit for arable land.

The following analysis is of a clay slate soil from Wexford:

Silica	62·4
Alumina	12·0
Peroxide iron	7·9
Lime	6·0
Alkali and magnesia	3·0
Organic matter and water	6·0
	97·3

The clay-slate soils are, in an agricultural point of view, the least valuable of the soils of Ireland, considering their elevation.

That formation termed graywacke, which is most abundant in the centre of the North of Ireland, may be considered as the point of meeting between the clay-slate below, and the sandstone above, and may be taken as either the lowest bed of the sandstone, or the uppermost beds of slate; hence it partakes of the qualities of both, but differs from either in containing masses of limestone contained in it, forming what was called transition limestone. Graywacke is stratified, has few organic remains, and is the first of the secondary rocks which contains lime to any amount. The fertility of a graywacke soil depends much on the rock which borders it: thus if it be quartz its fertility will be impaired.

I subjoin an analysis of the rock and subjacent soil of a district in the County Cavan: the contiguous soil was a limestone.

Graywacke Rock.

Silica	59
Alumina	12
Protoxide iron	4
Peroxide iron	,,
Lime	20
Magnesia and alkalies	3
Chlorine	1
Loss	1
	100

Soil.

Silica	63·0
Alumina	13·0
Peroxide iron	7·0
Lime	13·7
Magnesia and alkalies	2·0
Chlorine	·3
Organic matter and water	1·0
	100·0

The sandstone formations are very extensively diffused over the surface of Ireland, and, for the purpose of husbandry, no distinction need be drawn between the old and new red sandstones. They are composed of micaceous and siliceous grains, cemented together by calcareous matter, and by oxide of iron, which gives it its characteristic colour. There are three distinct beds described as existing in this island; the upper is a fine red sandstone, the middle is conglomerate, indurated sandy gravel, and the last consists of layers of hard siliceous limestone, capable of being split into thin tiles. It is found in Ulster, bordering the mountain limestone range in Tyrone, Fermanagh, and Monaghan. In Munster it is found at the edge of the same formation in Waterford and the neighbouring counties. It runs round the base of the slate hills of Tipperary; it occurs at the upper waters of the Shannon, and in the south of Mayo. From the area it occupies, and the thickness of its beds, it is one of the most important of the Irish series.

The soil formed from sandstone is dry and porous, loose, and very friable, with little aluminous and calcareous matters in them; such soils are much benefited by lime, by which they gain in tenacity, and their irony matter is acted on. Its open and loose nature renders it well adapted for planting trees, by allowing free progress to the roots, and it is the soil best fitted for fruit trees; all the cider growing counties of England are upon sandstone formations; for although the soil contains but little of alkali and lime necessary for the growth of plants, yet by allowing free space for the growing roots to travel in quest of food, a large extent of ground is searched out, and the materials abstracted. The soil, in its turn, is benefited by this process, for by cultivating deep-rooted plants, valuable aliments are brought to the surface in quantity, and when the useless stems are returned to the soil as manure, corn crops are then enabled to be raised off a sandstone soil which previously was not capable of raising them.

The following soil, No. 1, was taken from Derry.

Silica	75·9
Alumina and iron	4·6
Carbonate of lime	5·7
Alkalies	2·5
Chlorine	1·0
Organic matter and water	10·5
	97·2
	in 100 parts.

No. 2, from Cappoquin.

Silica	92·0
Alumina	3·7
Oxide iron	0·3
Carbonate of lime	1·8
Soda	0·50
Potass	0·50
Magnesia	0·40
Chlorine	0·4
Organic matter and water	14·0
	114·0
	in 120 parts.

Of these two analyses, No. 2 approaches more exactly to the formula of the sandstone, the excess of lime and of the sandstone, the excess of lime and of alkali, found in No. 1, being due to its contingency upon the basalt.

No. 3 is a specimen of soil from Tipperary:

Silica	83·0
Alumina and oxide iron	7·6
Carbonate of lime	1·2
Organic matter and water	8·0
	99·8 in 100 parts.

No. 4 is a sandstone sub-soil, situate a little east of Clonmel:

Sand and siliceous matter	84·50
Alumina and peroxide iron	3·80
Carbonate lime	1·60
Soluble salts, as chloride of alkalies and sulphate of lime	4·60
Magnesia	1·00
Water	4·00
	99·50 in 100 parts.

No. 5 is an ochrey slate from Tipperary:

Siliceous matter	91·00
Alumina and peroxide iron	1·50
Carbonate lime	0·40
Soluble salts containing potash and soda	2·00
Water	5·00
	99·90 in 100 parts.

Such a soil is peculiarly sterile, requiring both large quantities of clay and lime to bring it into a fertile state.

The carboniferous, or mountain limestone, forms the surface of a great extent of the central counties of Ireland. It is composed of beds of compact crystalline limestone, of various colours, from grey to black, traversed by occasional veins of calcareous spar; this immense field, occupying ninety miles by forty, is mostly horizontal, containing a few hillocks of inclined strata. The limestone of the neighbourhood of Dublin (calp) is situated lower than any of the primary rocks in its vicinity, and is an impure argillaceous limestone. It immediately follows the granite at the Black-Rock, and the quartz at Howth; in the Tralee valley it rests on sandstone. The soils vary much in depth, occasionally thin, composed of small angular fragments of rock, combined with detritus of the rock itself, and vegetable mould. In a sheltered situation, and with but little elevation, the soil produces corn and green crops, or, in pasture, a fine sweet herbage. It may be subdivided into

1st. The lower limestone.

2ndly. The calp or black shell.

3rdly. The upper or splintery limestone.

The first occupies the middle and southern counties.

The second, or calp district of Leinster, includes Dublin, Meath, and Westmeath; this is an impure black limestone, containing balls of clay ironstone. Some of the beds contain sulphur in the form of sulphuret.

The upper, or splintery limestone, is of little surface extent, and found on the sides of hills in Fermanagh, Sligo, Cavan, Leitrim, and the coal districts; it need only be alluded to.

The following is an analysis of a limestone rock from the neighbourhood of Philipstown:

Carbonate of lime	91.49
Silica	5·50
Alumina and iron	0·70
Sulphuric acid	1·72
	99·41

Soil from same district was thus constituted:

Silica	85·0
Alumina and iron	5.0
Carbonate of lime	7·4
Chlorine	0·4
Organic matter and water	2·0
	99·8

A moor soil from same locality did not differ from the above, except by containing 19 per cent. of organic matter and water.

Soil from River Tolka, near Dublin:

Silica	60·3
Alumina and iron	14.0
Carbonate of lime	12·4
Potass and soda	1·8
Chlorine	0·5
Organic matter	10·0
	99·0

By the addition of alkali as manure, large crops could be obtained from these soils, by growing those plants which require large quantities of lime, as tobacco, pease, potatoes, sainfoin, and clover.

I have taken an opportunity elsewhere to treat of the properties of marls; I may here mention their situation and composition: they are found above the new red sandstone in the more recent formations, and constitute an important constituent of the oolite and lias formations in England; in our country, they usually lie upon the new red sand-stone, and are occasionally found by it, forming the red marl, or mixed with a quantity of argillaceous matter; oxide and iron forming the blue marl. They are abundant in fossil remains, giving strength to the supposition that those beds are solely the residues of animal life extinct.

Magnesian limestone is found in the lower beds of the new red sandstone; it consists of thin beds of slate and limestone, and gypsum, placed over each other. It is a compact limestone of a yellow colour and consists of:

Carbonate of lime	54·35
Carbonate of magnesia	45·65
	100·00

mixed with a little clay and oxide of iron.

Beds of this limestone are found at Howth and Milltown, near Dublin; it occurs also at Belfast.

Concerning the value of this formation to the agriculturist, there is much difference of opinion. Mr. Tennant, who first stated that it was injurious to vegetation, sowed some seeds in a magnesian limestone, but they did not grow healthily, and he concluded, that the cause was owing to the magnesia it contained. Sir H. Davy found it to be used with advantage. The fertility or not of this soil depends in a great degree on its elevation. If found only at a moderate height above the sea, it produces excellent corn crops, and bears a short, green, sweet herbage. That it cannot be injurious to crops, is evident from the fact, that carbonate of magnesia is an ingredient of most plants; to flax it is essential. But when burned, and applied as manure, the case is quite different, for magnesia parts with its carbonic acid, and is rendered caustic much sooner than lime, and when burned, retains its causticity for months, so that when ground manured with it is brought into contact with the young roots of plants, they are immediately killed, and it is in this way magnesia acts injuriously on vegetation.

In the magnesian limestone districts of the north of England, vegetation appears only in patches, and is of a coarse character. I am inclined to think that there must be some other ingredient causing the sterility, besides the mere presence of magnesia. Where much humic acid exists in the soil, magnesia is not injurious, and on peaty soils the magnesian lime would be most useful.

Besides the mineral ingredients which we have decribed as components of soil, there is also, in every fertile soil, a quantity of vegetable matter in a decomposed state, in that state wherein it is soluble in water, and thus enabled to enter the rootlets of the plants and become sustenance for them. And in proportion to this quantity of soluble vegetable matter, so is, generally speaking, the fertility of the soil. The mere presence of vegetable matter is not sufficient, for it exists in great abundance in bog soils, but generally in an insoluble state; and one of the benefits of lime to such soils is, the capability it possesses of rendering vegetable matter soluble. This vegetable or *organic* matter, as it is termed, is mostly derived from the remains of the plants which grow on the soil previously, and where this quantity is not deemed sufficient, farm-yard manure and linseed-cake are extensively used.

During the deca of this vegetable matter (or humus, as it has been termed), a quantity of carbonic acid is given off, which is absorbed by the moisture of the surrounding earth, and becomes one of the nutriments of the plants. Two other substances are formed at the same time, possessed of acid properties. Like carbonic acid, they also contain a large store of carbon; like it they are soluble in water, and thus aid the growth of the crop.

If a dark-coloured soil be boiled for a short time with a solution of the common soda of the shops, a deep-brown coloured liquid is obtained, which, if some muriatic acid be added to it, a flocculent brownish powder will fall down, which is *humic* acid. If, instead of soda, we use a solution of ammonia, the substance thrown down will be *ulmic acid.*

These two acids are composed of carbon, hydrogen, and oxygen, in somewhat different proportions, thus:

	Carbon.	Hydrogen.	Oxygen.
Humic acid . .	63	6	31
Ulmic acid . .	57	4¾	38¾

When exposed to the air for any time, both these acids are converted into carbonic acid. They combine readily with the earths and alkalies of the soil, and become more easily soluble; thus the ulmates of the alkalies are very soluble. Ulmate of lime is soluble in 2000 parts of water, while ulmate of alumina requires 4200 parts of water. From this the value of lime is seen, where much vegetable matters exist in the soil, namely, that it produces a form of vegetable food which is easily soluble, and capable of being taken up by the tender roots.

These acids exist in the brown liquor of the farm-yard, which is so often shamefully let run to waste, and also produced by the decay of the manure in the soil.

The amount of organic matter or humus in a soil, may be known by burning the soil in a red heat for a short time, when the quantity of loss sustained by the burning very nearly represents the humus.

This quantity varies very considerably. In some soils, as bogs and peats, it amounts to 75 per cent. In the soil of a moor, I have found 20 per cent., but these are high quantities. The usual quantity varies from 2 to 10 per cent.; the latter is found only in stiff clays. The quantity required by crops is not very great; thus rye will grow on ground with only a fraction above 1 per cent., and barley between 2 and 3. Wheat requires above 4 per cent.

All soils contain water, and clayey grounds contain the most; it is essential to fertility, by dissolving the vegetable matters and saline substances in the soil, and carrying them upwards, and depositing them in the plant. Too much water, however, is injurious; by carrying these soluble matters downwards into the subsoil, and out of the reach of the roots of the crop, and by lodging in the ground, it reduces its temperature, and prevents those changes of decomposition taking place, which we have seen to be so necessary. The quantity of water contained in a soil is known by drying a portion in an oven and weighing; the loss indicates the quantity of water.

Having now stated the geological position, chemical constitution, and agricultural value of most of the soils of this country, it will be necessary to add but very few words. One remark worthy of remembrance is, that though some soils be naturally more productive than others, yet some circumstances may come into play to render it the contrary; such, for instance, as the expense of working a soil; this may compel a farmer to convert a good wheat soil into grass land. Again, where two different strata come into contact, the point of junction is always a more fertile district than either separately, for reasons assigned before. Lastly, though the rule hold generally true, that the soil is derived from the subjacent rock, yet some of the limestone soils of Ireland appear to be an exception, there positively being a destitution of lime in the soil; in some cases so much as 2 per cent. cannot be detected. From this it may be seen, how necessary it is that the farmer should be acquainted with the actual nature and wants of his soil, by a chemical analysis of its contents; since from the above it is evident, that a soil may become sterile from the want of an earth which possibly forms the entire soil four or five feet beneath.

CHAPTER III.

ON MANURES.

MANURES are substances which are capable of furnishing food to plants, and are divided into animal manures, vegetable manures, and mineral manures.

No matter what may be the constitution of soils, or their chemical and physical properties, there must be a certain amount of organic matter, in a state of decomposition more or less advanced, which goes to form vegetable mould or manure.

Vegetables, besides carbon, hydrogen, oxygen, and azote, contain a quantity of saline ingredients, these, excepting a little ammonia, are not found in the atmosphere, and are derived from the soil. If the soil does not contain them, it must be supplied by certain mixtures, natural or artificial, containing them. These mixtures are called mineral manures.

To supply these deficiencies, the substances commonly used are decayed plants, with the droppings and litter of animals, which contain most of the principles of organized being. Such is farm-yard manure—manures which supply many ingredients, as in this case, are *general* manures. *Special* manures are such as supply only one or two ingredients, as gypsum, sulphate of ammonia, marl, and wood ashes. These last, if spread over a barren soil, would not produce any crop. For a manure to be immediately efficacious it should have the mixed composition of general manures. It is in this way that blood and urine act so efficaciously.

Vegetable or animal matter, when dead, and exposed to the action of heat and moisture, with access of air, undergo changes of decomposition, whereby their elements are separated and formed into new combinations; the fermentation and putrefaction setting in, the more complex animal and vegetable principles are resolved into simpler chemical bodies, the earthy matters of the decaying substances are separated and deposited in the earth, while gaseous bodies are given off. The substances which undergo this process of fermentation, or decay, or eremecausis(*a*), most readily are those which contain nitrogen; for this reason, animal substances are soonest decomposed; a quantity of ammonia is formed, and, at the same time, carbonic acid is given off. Thus, in urine decomposing, one of its principles, urea, is resolved into carbonate of ammonia, by the intervention of water, which adds its elements to those existing in the urea; so that 100 parts of urea furnish 130 parts of carbonate of ammonia. This property of nitrogenized bodies appears to depend on the affinity of the nitrogen for hydrogen, which is supplied by the water, and ammonia is thus formed.

Dead vegetable matter, as wood, straw, leaves, &c., are transformed by this action of the air into a brownish-black substance, which falls into powder when dry; this "*compost*" is not the last stage of decomposition, for the atmosphere continues to exert its action, slowly and imperceptibly dissipating its combustible elements, forming water and carbonic acid. The farmer may very advantageously

(*a*) A term used by Liebig, denoting slow combustion.

make use of the progressive change in farm-yard manure or straw rotting; thus, if it were to be applied for green crops to a light land, it would be well to have it in the state just mentioned as *compost;* while if it were for heavy clay and a grain crop, it would be better that the straw should not be at all fermented; it would serve to keep the soil more divided.

Alkalies and alkaline earths contribute powerfully to this change and accelerate it. This has been long known to agriculturalists, who have used lime for that purpose. When the vegetable matters have arrived at the state of change just described, a brownish substance, sparingly soluble in water, readily soluble in alkalies, is formed; it is called ulmic acid, and has been found as a constant ingredient in the liquid of farm-yard manure. It unites with the alkalies and lime, forming ulmates of potash, soda, and lime, which are soluble, to some extent, in water, and are thus conveyed into plants.

The most energetic manures are of animal origin. All the substances which enter into farm manure have nitrogen as an element, by which means ammoniacal salts are produced, the most powerful agents in favouring vegetation. In Flanders, putrefied urine is used as a manure, which contains a large quantity of carbonate of ammonia. The value of guano likewise is in proportion to the quantity of ammonia it is capable of furnishing.

Liebig has shewn that the atmosphere close to the ground contains a small quantity of ammoniacal carbonate; the same salt has also been found in rain, snow, and spring water. According to this chemist this ammoniacal salt is added to that contained in the manure, both concurring to furnish nitrogen to the future crops.

The soluble parts of manure being thus so valuable and volatile, every care should be taken to preserve them, if possible, without change or loss. Hence, any expense undergone for this purpose is an ultimate saving. It has been well remarked by M. Boussingault, that at the first sight one may judge of the industry and degree of intelligence of a farmer by the care he takes of his dung heap.

Care should be taken that the liquid portion do not run to waste, but be gathered into a tank in the ground. External rain waters should not be allowed to mix with it; and lastly, manure heaps should never be raised high. It is an advantage, where the manure heap is, to have the ground hollowed in a concave form, and to be closely paved. In warm weather, its surface should be kept moist by being watered; it is also well that all the materials destined for manure should be mixed together, so as to have a uniform strength on the whole farm.

In the fermentation of animal manures, carbonate of ammonia flies off rapidly, which can be retained in the heap by watering it; also, by heaping fresh dung on the surface the same object is gained. A free current of atmospheric air is necessary, so as to cool the surface of the mass. Should the whole have already proceeded to fermentation, the volatile matters can be retained by covering it with a layer of surface soil, which will absorb the vapours, and will itself be converted into a manure.

In order to prevent this loss, it has been proposed to convert the volatile salts (of ammonia) into a fixed salt; and to this end sulphate of iron or sulphate of lime (gypsum) has been added to absorb and fix the ammonia.

It is not desirable to check fermentation in a manure, but only to moderate it; thus, in good farm-yard manure, the upper portion should exactly be as as it was when carted to the spot; the layer under it is slighly altered, and smells of ammonia faintly; lower down, the straw has lost its consistence, breaks, and crumbles readily, and is fibrous; and its colour is much deeper: close to the ground, the colour is black, the sulphates existing in the heap have been converted into sulphurets, and it smells strongly of sulphuretted hydrogen. This state is proper for a manure to be spread on the ground; for all organic matter must have formed ammonia to a certain extent before it can be useful to vegetation; but as this change would be undergone, if the manure were deposited fresh from the animal, it becomes a question—is it advantageous that manures should ferment? The answer is, that as every manure fermenting in a heap suffers a loss, in some cases amounting to one-half, and that as this loss is prevented by using the manure *fresh*, there can be no hesitation which course should be followed. Fresh manures are in no way injurious to ground, except when added in too great quantity. To cold soils, however, fermented manure is more serviceable, as it warms the soil and stimulates the growth of vegetation more rapidly. Fresh manure is also objectionable for corn crops, as it contains seeds of weeds and eggs of insects undestroyed.

Farm-yard manure, obtained from horses, cows, pigs, and litter, contains, according to Boussingault, on an average

Dry substances	20·7	per cent.
Water	79·3	„
	100·0	

And its composition is thus:

Carbon	7·41
Hydrogen	0·87
Oxygen	5·34
Azote	0·41
Salts and earthy matters	6·67
Water	79·30
	100·00

Azote must be present in a manure to render it valuable; but it must be in that state that it can undergo fermentation, and unite with the hydrogen, to form ammonia; in proportion as it contains azote in this state, so is it efficacious. Straw, leaves, and weeds, contain a small quantity of nitrogen, and are serviceable as manure. What are called green manures may be more valuable in other ways: and it is a question for the agriculturalist to decide, whether he will use them as fodder or manure. Cakes, after the oil has been pressed out of the grains and seeds, are excellent manure, as they contain almost the whole nitrogen contained in the seed; they are easy of carriage, and can, therefore, be had where ordinary manure cannot. They are either scattered on the field, or else mixed with water or liquid manure, and allowed to ferment, and then watered on; it acts best in wet weather; its effects on some crops are highly beneficial, as turnips, potatoes, and spring wheat.

Blood and *muscle* are highly nitrogenized substances, and act beneficially; they are usually mixed with other refuse in butcher's heaps, and mixed with marl, and then buried in the soil; it is a most powerful manure.

Animal Excrements.—The manure of the horse is more powerful than that of the cow, which latter is far more watery. Pigeons' dung is a powerfully active substance, requiring to be used with prudence; mixed with coal ashes, it has been applied to clover with great success.

Analogous to this last is guano, which is the excrement of sea birds inhabiting the coasts of the South Seas; besides excrement, it is composed of the remains of penguins, albatross, gannets, booby birds, and seals; it is found at Chinca and Payta, in Peru and Chili, and, more lately, at Ichaboe, and a few smaller isles off the west coast of Africa: of the two varieties now in the market, the Peruvian is in the best state of preservation and the most valuable. Its composition may be thus expressed, as per average:

Azotized animal matter, including urate of ammonia, together capable of affording from 8 to 16 per cent. of ammonia, by slow decomposition in the soil	50·0
Water	11·0
Phosphate of lime	25·0
Phosphate of ammonia, oxalate of ammonia, phosphate of magnesia, together containing from 5 to 9 parts of ammonia	13·0
Siliceous sand	1·0
	100·0

Dr. Fownes has recently examined some African guano, which was brownish, and of a disagreeable odour; it contained in 100 parts:

Oxalate of ammonia, uric acid, traces of carbonate of ammonia, animal matter	66·2
Phosphates of lime and magnesia . . .	29·2
Phosphates and chlorides of alkalies, traces of sulphates	4·6
	100·0

From a sample of African guano, of a brown colour, and strong odour of ammonia, I obtained

Oxalate of ammonia and carbonate ammonia	65·0
Uric acid and organic matter	2·4
Phosphate of lime and magnesia . . .	20·0
Sand	1·5
Phosphate and muriate of soda, sulphate of potass	4·2
Water	6·9
	100·0

As has been well remarked by Dr. Fownes, it is not easy to find a manure containing so many of the ingredients necessary to the support of the plants. It yields soluble salts, bone-earth, and ammonia, either ready formed, or in the state most favourable for its production. The above are analyses of good guano; but the adulterations are frequent, and to a great extent; and no farmer should buy any quantity, no matter how small, without having it specially analyzed.

There are few crops to which guano has been applied that it has not repaid the farmer with interest: applied to Swedes (turnips) it produced, when 3 cwt. per acre was used, above 23 tons; and 5 cwt. of guano produced 32 tons of white globes; and in general it is superior to farm yard manure for this crop. Four cwt. applied to Connaught cups has nearly trebled the amount which the unaided soil produced.

It is a good practice in applying guano to mix it with another manure, as half guano and half farm-yard maure, or rape dust, or the nitrates; but lime or wood ashes should not be used, as these tend to drive off the ammonia from the guano. Nor should it ever be applied in contact with the seed, as it tends to check the development of the embryo.

Human manure is a valuable and powerful agent to vegetation. In this country too little attention is directed to it; but its value is appreciated in Flanders and China. Its power depends very much on the aliment consumed by man. Human urine is a very complex fluid, and in putrefying developes a quantity of ammoniacal salts, and has a prompt and energetic action when diluted, and applied with a water cart.

The constitution of human urine is thus given by Berzelius, containing in 1000 parts

Water	933·00
Urea	30·10
Uric acid	0·10
Muriate of ammonia, free lactic acid, lactate of ammonia, and animal matter	17·14

1000 parts contain 68 parts of solid matter, the remainder consisting of phosphates, sulphates, and muriates.

Urine should be used quite fresh. When it putrefies it abounds in ammoniacal salts, but it is far less active than before. If it be not mixed with solid matter it should be largely diluted, and laid on with a cart.

The manure termed urate is urine mixed with gypsum, pouring off the extra liquor, and crushing the gypsum after being dried. As a manure it is not at all comparable to the urine itself; and where the latter can be saved, the urate ought not to be purchased.

The urine of cows and horses contains less water, and is consequently stronger than human urine.

Those manures which either directly or indirectly furnish ammonia should never be formed into a compost with lime, potash, soda, the effect of which would be the loss of nearly all the ammonia contained. The chief value of urine depends on the quantity of urea it contains. Urea has a larger proportion of nitrogen than either flesh or blood: it consists in 100 parts of

Oxygen 27; hydrogen 6; carbon 20; nitrogen 47.

When urine has putrefied, the quantity of urea lost amounts to three-fourths of the whole, so that only one-fourth remains; from this the advantage of using urine fresh can be seen at once. The solid matter contained in the urine of animals varies; thus, in 10,000 parts the amount of solid matter was as follows:

SOLID MATTER.

	Organic.	Inorganic.	Total.
Man	230	76	306
Cow	500	200	700
Horse	270	330	600

So that the relative value of their urine stands thus: 1st, cow; 2nd, horse; 3rd, man. The quantity given above, if stated as pounds, may be taken as the average quantity voided by a cow in nine months; if this be let to run to waste there is, as often occurs, a loss of 700lbs. of solid matter, worth three guineas. This solid matter, weight for weight, is equivalent to the best American guano.

When urine is treated with a little sulphuric acid, and mixed with bog-stuff, or, what is better, charred peat or turf, so as to absorb all gaseous emanations as they arise, it is a valuable manure.

Shell fish are a most valuable mauure. Where muscles and star-fish are raised by dredging, agriculturists on the coast should purchase them up, as these animals, especially the star-fish, contain in their outer covering a large quantity of phosphate of lime added to their animal matter. Fresh water muscles and other shell-fish, with vertebrate fishes, where they occur in any quantity, should be immediately purchased: and moderately salting, which, while it would kill them readily, would also serve as an additional manure. To stiff lands the shells would be a valuable addition, especially if it were deficient in lime. When collected, the shells and fish may be thrown into a heap, and let lie until an unpleasant odour is emitted; then having the shells smashed, and the whole mixed with bog-stuff or earth, and laid on to the amonnt of sixteen bushels per acre. Along the coast of Ireland vast quantities of this manure might be gathered at an expense of about nine shillings per ton, which would not only supply a cheap and valuable manure to the farmer, but also a source of employment to the inhabitants of the coast.

The effect produced by carbonaceous manures on corn crops, or tuberous plants, renders the question of the *modus operandi* of nitrogen or ammonia a very complicated one. If it could be proved that in corn crops the amount of starch, sugar, and gluten were the same, no matter what were the manure used, it would at once appear that the carbon was derived from the air, as stated by Professor Liebig; but from the above fact the converse would appear. But, says Liebig, supply a plant with nitrogen and it will then fix more carbon from the air; the nitrogen of the manure, entering the plant, requires nearly four times its weight of carbon to be abstracted to be converted into gluten, and we have the nitrogen performing a double office of supplying a particular ingredient, and also of indirectly causing another to be absorbed. But, as M. Bree remarks, this can only apply to azotized crops, for in turnips and potatoes the proportion of nitrogen to carbon being as 1 to 10, or 15, the carbon already exists in proportion far beyond what is necessary to produce gluten or albumen. If Liebig's assertion be true (and future experiment can alone settle it), it would appear that manures bear a closer relation to crops than ever; for if we apply urine or guano to turnips or potatoes, a quantity of azote will be wasted, as the crops contain only 1 part of albumen to 9 of unazotized matter: while in the case of beans and peas, one part of albumen is accompanied with two of unazotized food; it would appear also that azotized manures should only be used with azotised crops.

The indirect action of nitrogen, as given by Liebig, involves the question of stimulation; but what is stimulation—is it a similar or even analogous action in the animal and the vegetable? Upon the animal frame a stimulant causes an increased action of the respiratory and circulating organs, with nervous excitement; in a plant, in which there is neither a respiratory nor vascular system at all analogous, and no trace of a nervous system, can such a stimulation occur? And though they have a fluid (sap) moving, it is not a circulation, nor has the application of any manure ever been known to increase the velocity of its current. Having no nervous system, the roots cannot be said to extend *in search* of food, but rather to grow because they have *already received* it: for to search for food implies a nervous system, which does not exist. The rapid growth of plants, when supplied with certain substances, cannot be due to *stimulation*, in the animal use of the term, but simply to the receiving a large quantity of that substance into the body of the plant, and thus increasing its bulk. And it may be added in proof, that what are called stimulants are *soluble bodies*, such as the nitrates or the alkalies, which can readily enter the plant and add to its bulk: insoluble bodies cannot stimulate. Stimulation, then, when applied to vegetation, means the capability of receiving a large amount of a soluble body into the constitution of the plant, whereas the action of stimulants on the animal does not imply an increase of bulk.

The idea of stimulation must be rejected altogether, and the effect of powerful manure is to supply plenty of nutriment; and it can only supply the nutriment which it contains in itself, it cannot make the plant select other food, which is the animal notion of a stimulant.

The manures of organic origin which we have been just examining, contain a small quantity of saline matters, which appear as ashes if they be burned away; these saline matters add to the efficiency of the organic manure, by supplying additional elements to plants, and even the most powerful organic manures contain very sensible quantities of salts, both soluble and insoluble; yet in some cases this amount may be insufficient to supply the wants of an impoverished soil or a peculiar crop; and the defect of the soil must be remedied, or the demand of the crop supplied, by substances, from their composition termed "mineral manures," and from their office, "special manures." For instance, clover, lucerne, and sainfoin require gypsum; corn crops require silica and phosphates of lime; tobacco and the vine demand salts of potash. This subject of special crops requiring special manures, has not yet received all the light which science is capable of throwing on it; and deserves the close attention of accurate observers before any definite principles can be laid down.

The first of mineral manures in importance is lime; it is rarely met with in soils of the primary rocks, but it is abundant in those derived from the secondary and tertiary formations. In Ireland, the centre of the island being one extensive limestone plain, with arms ramifying on every side into the counties towards the sea, there is no deficiency of limestone, as it has been found in every county except Wicklow. As far, therefore, as the presence of a surface, limestone-rock being so remarkable a prominent feature of this island, one would think that this mineral manure would not be in much demand with us, yet no where is it much more so, or more deservedly; for if we consider that, as has been mentioned before, the soil of many districts covering the limestone contains little or no carbonate of lime, being formed of alluvial or diluvial deposits, we shall immediately understand how beneficial its action must be; besides, even were lime present in the soil, if vegetable matter exist to a great extent, additional lime will be required to bring into decomposition and render it soluble and fit for nutriment to plants.

Lime is applied to the soil either in the caustic state as quick-lime, as it is termed, or as a carbonate of lime, as it exists in limestone. The former practice is termed *liming*, the latter, *marling*. The quick-lime is obtained by burning the limestone in kilns, the carbonic acid being driven off. Limestone, when pure, consists of:

Lime	56·3 parts.
Carbonic acid	43·7 „
	100·0

So that from 100 parts of pure limestone, about 56 parts of quick lime may be obtained; but it is very rare to find limestone so pure as above indicated; it usually contains oxide of iron, clay, and fine sand, to some extent; in some cases, as in the calp of the upper limestone beds, the quantity of clay is so great, as to render the limestone unfit for burning.

When fresh burned it is white, destroys animal and vegetable substances, and dissolves in 1630 parts of cold water. Lime, when slacked, is much less caustic.

Ground which has not sufficient lime in it never attains a high degree of fertility. Where the sub-soil is calcareous, lime is rarely so beneficial to the upper soil, and it should be remembered, that lime cannot be beneficial, except organic matter pre-exist in the ground, and can, therefore, never be substituted for, or take the place of organic manures.

The geologic constitution of a country furnishes indications whether lime would be beneficial or otherwise. Thus, where the surface-rock is crystalline, or of igneous origin, as granite, or micaceous felspather, or quartzose, lime would probably be beneficial. A direct analysis to determine the presence of lime, would put the question at rest.

The quantity of lime to be applied to land, varies with the nature of the land and the quality of the lime. Light soils require much less than clays or strong grass land. Under 200 bushels per imperial acre, perhaps, would suit the former. The average employed on sandy soils is 80 bushels. On clayey and mossy soils, from 200 bushels, upwards; as much as 400 bushels per acre have been applied, with an immense potato crop resulting. On lands to be reclaimed before the first sewing, a quantity less than 200 bushels will scarcely be worth applying. The character of the soil would also indicate which of the varieties of lime would be most proper to apply. Thus, on stiff, clayey, and tenacious soils, corn-gravel or limestone-gravel would be a better application than chalk or caustic lime: while on the other hand, in light and sandy soils, a clayey limestone, marl, or chalk, is preferable.

There is no doubt that the superior efficacy of quicklime over every other form of lime, is due to the fine state of powder in which it exists, and its greater solubility than the other states.

When lime is to be applied, the soil should be quite dry, and the best time is the commencement of Autumn. If the soil be damp, or the weather rainy, the lime does not diffuse itself equally, but cakes into small lumps, is not readily converted into a carbonate, preserves its causticity for a longer period; and where the young rootlets spread themselves through the land, they are frequently killed by the lime.

In liming ground, the great end in view should be, to have it equally diffused over the whole; on this account, I think, in liming grass-land, it would be better to do so before it is broken up, and not, as is usually the case, afterwards. If thus managed, the same quantity of lime appears to exert a more powerful and beneficial effect upon the soil. The most proper season for laying it on is Autumn.

Marls are compound earths, formed of carbonate of lime and clay in different proportions; sometimes sand takes the place of clay, hence the term, clayey marl and sandy marl. The proportion of carbonate of lime varies from 15 to 19 per cent.; its colour varies, and is no good test of its value.

The characteristic property of a marl is its crumbling down to dust or powder, when exposed to the atmosphere. It is from this property, that it acts so beneficial in its application to grounds; the minute particles of carbonate of lime being easily spread over ground. When laid upon stiff, clayey lands, its importance may be understood by taking into consideration its tendency to keep its particles asunder, and thus allow superfluous water to drain through the soil.

On the other hand, upon light, sandy soils a marl containing much clay (argillaceous marl) acts beneficially in a two-fold way. First, by the carbonate of lime added, and secondly, by the clay. It is chiefly on sandy, light earths that *marls* should be applied; upon stiff soils, where much clay already exists, liming is to be preferred.

Marls act both mechanically and chemically upon the soils to which they are applied; mechanically by their clay, and chemically by their lime. As some marls contain a minute proportion of azote, one or two parts in 1000, it is probable they may act in a third capacity by supplying this valuable element.

Like lime it should be spread uniformly, and in a fine powder; hence the useful practice of exposing it for some months to the atmosphere previously to its application.

The quantity to be applied, varies according to the nature of the soil, and the amount of lime which it contains. The action of both lime and marls ceases after some time, and then it requires to be renewed; and this is usually explained on the fact, that crops raised off, take away a certain proportion each harvest, and much being carried lower down into the soil, out of the reach of the rootlets, by the action of continued rains, this diminution must be made good to make up the average production of the land.

Besides the application of lime as limestone, or chalk, or marl, there are other forms in which it is usefully employed. Limestone-gravel is an article worthy of consideration; it consists of masses of stone pebbles and slate concreted together, which, when spread on and mixed with the ground gradually, loosens and fertilizes the soil, in proportion as its gravel mixes with it. It is chiefly valuable on stiff, clayey soils after they are drained. This gravel forms the sub-soil in many places, and is easily procured by digging down for it.

The following is an analysis of marl from Longford :—

Insoluble siliceous matter	4·9
Alumina and peroxide of iron	3·8
Carbonate of lime	77·7
Soluble salts of chlorides, and sulphates of soda, potash, and lime	2·5
Water	10·6
In 100 parts	99·5

A rich marl from Leitrim:—

Insoluble siliceous matter	15·2
Alumina and peroxide of iron	6·60
Carbonate of lime	64·9
Soluble salts, chloride of sodium, sulphate of lime	4·4
Water and loss	8·8
	100,00

Shells, and Shell Sand—Sea Sand.—These are valuable manures in proportion as they abound in shells, they are useful to almost all soils and at all seasons. Their effects are not near so powerful as lime, and the quantity applied might be increased one-half(*a*).

Sea Weed is a good, though not lasting, manure; it produces luxuriant vegetation, and good crops of potatoes. To increase its permanent effect, it is well to mix it with earth or peat, and it ought to be applied fresh. It contains a large quantity of the salts of sea-water, and is equivalent to its own weight of farm-yard manure.

Having now given a sketch of all the different forms in which lime is applied to soils, it will be necessary to say a few words regarding its action: a perfect elucidation of its various effects on both crops and soils is yet to be given. It is a subject on which much has to be learned, and will

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(*a*) The coral sand of the south and west of Ireland is a most valuable manure; it is composed of sand, sea shells, coralline remains, and organic matter, containing a considerable quantity of nitrogen: the coral contains a large proportion of phosphate of lime; and the sand, when moist, contains sea salt. All these ingredients conjoined tend to render it a very beneficial manure. Where it is cheap, it is used in large quantities, so much as 40 tons per acre.

occupy all the information and talent which can be bestowed upon it.

Lime, whether quick or carbonated, acts in a two-fold capacity, mechanically and chemically. Much of the advantage derived from its application to clayey soils is due to its physical property of lessening the tenacity and increasing the porosity of the original soil: so, also, by applying marl to sandy soils, it serves to bind them more together, and make them more retentive of moisture. It is in this way said to be cooling to hot lands; but if fresh lime be wished to be applied to sandy lands, it is well to mix it previously with a little clay, lest when the soil is anyway wet it would combine with its sand, and form a gritty mortar, rendering it difficult to be worked.

This mechanical effect is well obtained when the form in which the lime is applied is either calcareous sand, gravel, or shells: these last, on stiff land, open and loosen the clods, and allow the young roots to shoot their radicles in every direction. Where a soil is destitute of calcareous ingredients, lime acts beneficially, by becoming one of its earthy components; to soils, however, which are nearly or entirely destructive of vegetable matter, it is absolutely injurious, and it is in this way, its application to over-wrought soils, that we explain its hurtful effects on some lands.

The chemical effects of lime are various; and are chiefly exerted on the organic matters contained in the soil; when in the caustic state it is destructive of animal and vegetable life, hence its utility as an application. When weeds are to be got rid of, its action on dead vegetable matter is somewhat different; in some grounds, especially those which are moist, this vegetable matter, instead of going through the regular process of decay, and terminating by the evolution of certain gaseous combinations, stops short, forms a compound—a solid substance, which is quite insoluble in water. This process takes place in bogs, marshes, and places where the water is stagnant. A number of acids are formed, which give well-marked, sour qualities to the soil; these acids occasionally unite to the oxide of iron in the soil, and even where it may have preexisted as a peroxide the imperfect oxidation of the vegetable matter caused the iron to be reduced to the state of protoxide, and to form insoluble salts with these newly-formed acids. The iron in this state of combination is a positive injury to any crop, and must be peroxidized before any benefit could be derived from the ground. To such soils lime is beneficial in this way, it unites with the vegetable acids, and sets the protoxide of iron free, which latter, when uncombined, passes rapidly into the state of peroxide, which is a usual ingredient of crops; exposure of the soil by deep ploughing facilitates this conversion; but the action of lime is not confined to this—its combination with the above acids are soluble in water, are taken up by the moisture of the ground, and thus enter the roots of the plants, and furnish lime to the plants. Also, by the action of lime on decomposing vegetable matter, a quantity of carbonic acid is formed, which, combining with the alkalies and earths of the soil or manure, enters the plant, and is one of the modes by which carbon is supplied to the growing plant, especially in its early life. Indeed, so frequent is this formation of carbonic acid, that it gives some reason for the supposition, that lime acts beneficially on sour grounds, by decomposing the acid matters gradually, and converting them into carbonic acid, in which state only they are fit for nutriment. According to this supposition, where it is required to be applied to land abounding in undecomposed vegetable matter, it should be applied hot, in a powdery state, and in abundant quantity; but if it be necessary to apply it to land in tillage, it is better to use it in the state of carbonate, varying its state of mechanical aggregation to the properties of the soil which needs it; and the quantity employed should be less, using it more like other manures; and mixing it with clay, sand, or vegetable matter, according to the necessities of the land. Composts of this kind are generally far more efficacious than simple applications of either ingredients. Great care should be used by the agriculturist to make himself informed of the exact nature of his own ground, and to apportion well the several quantities of lime and earth, according as his land is heavy and cold, or light and warm.

Bones are a compound animal substance, consisting of a large quantity of earthy matter, filling up the cells of a substance called gelatine, analogous to horn. The bones of the cow consist of

Phosphate of lime	55½ parts.
———— magnesia	3
Soda and common salt	3½
Carbonate of lime	3¾
Fluoride of calcium	1
Gelatine	33¼
	100

From the above it is seen what a valuable manure bones are, containing so much animal matter, besides the inorganic ingredients of lime, magnesia, soda, common salt, and the acid of bones (the phosphoric), all which exist in fertile soils, and are so largely abstracted by corn crops. The bones of fat young animals are best. When bones are not crushed, their action is far more permanent than when in the state of dust. The effect of bones on turnip crops is remarkable, and superior to any other manure: the average quantity to be applied is from 30 to 40 bushels per English acre; if dibbling be used, a less quantity, from 15 to 20 bushels, will suffice. It acts most advantageously in dry seasons and on dry sandy soils. Fermented bones are superior in their immediate effects. By the use of bone dust large quantities of waste land might be brought into use for dairy husbandry, and, consequently, the cultivation of grain increased. The most useful ingredient is the nitrogen in the animal matters, which amounts to nearly 8 per cent. of the whole. When the bones are burned, a quantity of ammonia is formed, which is readily appropriated by the crop. This manure is absolutely essential to old pastures, to renew the waste and loss, drawn off in the shape of milk and cattle exported, otherwise the exhaustion would be so great that in time only the poorest grasses could be raised off it.

As the phosphate of lime is to a great extent insoluble, only a small portion, that soluble, can have an immediate effect on the grasses: to obtain this last on a great scale, the phosphate of lime is rendered more soluble by treating the bones with three-fourths their weight of sulphuric acid (oil of vitriol), diluted with its own weight of water; by this means a sulphate of lime or gypsum is formed, and a soluble super-phosphate; and in this form it is eminently adapted to stiff soils. After adding the acid to the bones, it is well to let them act together for twenty-four hours, and mix them up with a large quantity of dry earth, and apply this compost at the rate of four bushels of bones per acre.

Rape cake, or the refuse of the seeds of rape after the oil is expressed, is a valuable addition to land for corn crops; it may be used as a top dressing, or drilled in; it also increases the produce of both turnips and potatoes, and seems to act better during moist weather or occasional rains. One ton per imperial acre is a good dressing for potatoes. It is a valuable top-dressing to young wheat in spring; its action depends, in a great degree, on the quantity of nitrogen it can furnish to soils; this is evolved in the state of ammonia, and, as regards its immediate action, it may be classed with ammoniacal manures; but its permanent action is to be attributed to the organic substances it contains. It contains a large quantity of carbonaceous matter, of which, though no doubt it must be beneficial, the amount of benefit we cannot at present decide.

Malt dust is equally nutritious with the above, and may be used in the same manner.

Wood Ashes and the Ashes of Vegetables, as they contain all the salts and inorganic substances which plants raise from the ground, ought to be a useful manure, and in uncivilized countries they are used frequently, and sometimes as the sole manure; but in more advanced society the price they attain to, owing to the potash obtainable from them, prevents them being used much by the farmer: they are particularly fit for gravelly soils. Fifty bushels per imperial acre have been applied to turnips and potatoes, and they have increased the bulk and the weight of produce remarkably: and 1 cwt. mixed with common salt or guano per acre, has increased enormously the weight of both straw and grain of winter wheat. When applied to grass land it destroys the moss and increases the herbage.

Turf Ashes.—Turf appears to be the last stage of change which the atmosphere is capable of producing on vegetable matter exposed to moisture; and is composed of, besides carbonaceous matters, debris of plants, humus, a little ammonia, or nitrogenized matters; it contains about 5 per cent. of ash. What is remarkable in these ashes is the small quantity of phosphoric acid or phosphates found existing in them. Indeed, Boussingault, with the majority of chemists, has not been able to obtain any phosphates at all. While Weiyman found from 2 to 3 per cent.

The ashes generally consist of carbonate and sulphate of lime, clay, and silica, gelatinized and rendered soluble; alkaline chlorides and sulphates, and oxide of iron.

Ashes which are very red and weighty ought not to be used, as they contain an excess of iron, which is contained in the turf, combined with sulphur, which, by the burning, has been converted into sulphate of iron, an energetic poison to plants. Good turf ashes should be white and light: such ash is good manure for any crop, but especially for clover; in that nearly rivalling gypsum. They are spread in spring in Holland, by the hand, over clover, and next year an abundant harvest of wheat may be obtained: it is equally valuable for a hop crop; and a little placed at the base of the stem preserves the plant from insects.

From 70 to 90 bushels is the proper quantity for dressing an acre.

Alkaline Salts, or those which have a base of potash or soda, are valuable additions to soils; to these bases wood ashes owe their efficacy. As we have mentioned in another place, certain plants require alkalies for their nutrition: such as the vine, which contains potass united with vegetable acid, tartaric acid. Tobacco contains a large quantity of potass. The leaf of the oxalis acetosella (sorrell), contains binoxalate of potash, and the saltworts (Salicornia) contain a large quantity of soda.

Potash and soda naturally exist, but in a very small quantity in soils. Common salt has been applied in France, with great advantage, to barley, wheat, lucern, and flax, to the amount of from 1 to 2 cwt. per acre. Yet it has also been applied to grounds without any benefit. This may arise from the soil itself containing already a sufficient quantity of the mineral. Ground near the sea is little benefited by it, because vapour and mists off the sea deposit abundance of chloride of sodium in the ground.

Nitrates of potash and soda are valuable dressings to wheat and clover, and grain crops generally; but the manner of their action is involved in some obscurity. Besides the action of the base, the nitric acid furnishes a proportion of nitrogen to the plant. The action of nitrates on vegetation is remarkable in deepening the green tint, and increasing the growth of leaf. When applied to potatoes, it hurries them on, but the tubers are less, both in size and weight. The usual quantity applied is from 1 cwt. to 1½ cwt. per acre. No doubt the alkaline base is of great activity, for in some cases the nitrate of potash appears to act more beneficially than the soda-salt; but the other ingredient of the salt, nitric acid, appears to furnish nitrogen occasionally to vegetables.

Nitrate of potash or soda, when applied separately, or when mixed, to hay or potatoes, increased the crop on every variety of soil; but the produce is greater if both salts have been previously mixed. In moist seasons, these salts do not appear to benefit grain crops, the straw being increased and the grain lighter. Soot is similarly circumstanced; these crops give a larger quantity of oats after hay, and at half the expense of farm-yard dung.

Common Salt.—This important substance is found in beds deposited from ancient lakes, and as an efflorescence on the surface of the earth. It occurs in the tertiary formations of England and the Continent, as the mineral rock salt, but does not occur in Ireland. It is a chief constituent of the salts of sea water, and is found in all sea plants and most salt springs. It is a chemical compound of chlorine and the metal sodium, the base of the alkali soda, and contains in 58 parts

Sodium	23 parts
Chlorine	35 ,,
	58

The coarse rock salt contains besides small quantities of sulphate of magnesia, and lime, and chloride of magnesia: these impurities are all useful ingredients when used as a manure.

The action of common salt requires to be studied under different points of view, and its efficacy appears to be owing to many combined causes. 1st, The localities in which salt acts favourably. This substance, like lime or gypsum, acts favourably on soils which are destitute of this ingredient; hence, on inland situations its effects are more evident than in the proximity of the sea, where the spray of the ocean is carried miles inland, and deposited in a whitish crust upon the soil. To such lands, already supplied in abundance, any further addition would be an overdose and a poison. It assists in the decomposition of animal and vegetable matters, and in soils where there is much hard, insoluble matters, it would be usefully applied in small quantity. Common salt is very soluble in water, and consequently in elevated and exposed situations it is liable to be washed away down through the soil by frequent rains, and in such situations a dressing of it would be beneficial.

It is a constituent part of sandstone rocks, and to such soils it would be scarcely necessary to apply it. Common salt enters into the composition of the ashes of most plants, and on that account a small portion appears to be necessary for all soils.

Soda, when combined with sulphuric acid, forms sulphate of soda or Glauber's salt; which may be used in place of the above, or as a substitute for gypsum, on lands containing much lime. It is beneficial to grass lands, or as top dressing to potatoes and turnips.

A mixture of two of these salts is more beneficial than an application of either separately.

Gypsum, or *Plaster of Paris* (sulphate of lime), is one of the most powerful of special manures; it is a combination of oil of vitriol and lime. It is found in scattered masses in England; but in this country it is found in beds, as at Carrickfergus; and it is mostly confined to transition and tertiary formations. Its average specific gravity is 2. It is met with either combined with water (hydrous), or uncombined with it (anhydrous). For agricultural purposes the hydrous variety is the most useful. Some varieties of gypsum contain carbonate of lime, in a few cases as much as thirty per cent.; but the agriculturist should avoid this, and only purchase the purest sulphate of lime.

One part dissolves in 333 parts of water, and communicates to it the well-known property of hardness. The hydrous variety is the most soluble: it appears to be this small, dissolved portion which enters the vessels of plants.

I have analysed gypsum from the neighbourhood of Carrickfergus: it is silky-white, remarkably pure, being free from carbonate of lime or metallic impregnation. In 100 parts there were

Sulphuric acid	48·2
Lime	32·2
Water	19·4
	99·8

The advantage of gypsum over other lime manures is, that it is more easily dissolved, and fit to enter into the substance of plants—that it only requires powdering before application, and never requires burning like common lime.

If gypsum be heated with a little decaying vegetable matter, a portion of its sulphuric acid will be decomposed and sulphur set free. This operation is performed sometimes by nature in the cells of plants. Thus Stange found sulphur in the sweet and bitter almond; and Garot obtained from the mustard seed a compound containing sulphur.

The drier the soil the more adapted it is for gypsum, which is totally unfit for wet, undrained clays. The farmer should recollect that this manure is an application for his crop and not for his land; that it does not improve his soil mechanically, but is acted upon chemically by the plants. In fact, the chief utility of sulphate of lime depends more on its sulphuric acid than its lime; and this explains why the purer the sulphate the better it acts.

When it is sprinkled on growing crops either of two things occur; 1st, the portion of gypsum which is dissolved in the moisture of the earth is taken up by the plant and deposited in its tissue; this is what happens with clover and pulse: 2nd, the soluble portion taken up by the plant is decomposed, the sulphuric acid uniting with potass or soda in the vegetable, and the lime becoming a carbonate; or sometimes the soluble sulphate is totally decomposed before entering the plant by the vegetable matters of the soil, and one of its constituents, sulphur, enters into the plant.

As gypsum is soluble it should not be applied on the ground in wet weather, lest it be washed away, nor in great drought, as it cannot be dissolved and enter the vessels of the plant. Sprinkling it on a little before the morning or evening dew is most beneficial. Its effects on corn are very trifling, but that on leguminous plants cannot be approached by any other agent. It is not beneficial to natural grasses, but only to artificial meadow. The quantity of gypsum proper to apply to meadow or green crops is variable, from 2 to 5 cwt. per acre.

Spring is the best time (when the weather is mild) for laying it on meadow.

The following questions were addressed by M. Boussingault to agriculturists living in different districts of France, in order to determine the value of gypsum considered in its relations to agriculture.

1st. Does gypsum act favourably on artificial meadow?

Forty-three answers returned. Forty affirmative. Three negative.

2nd. Does it act favourably on artificial meadow when the ground is extremely wet?

Ten answers. No; unanimously.

3rd. Can it take the place of organic manure, or of humus in the soil; in other words, can a sterile soil, by the mere act of using gypsum, support artificial meadow?

Seven answers returned. No; unanimously.

4th. Does gypsum in a sensible manner increase the harvest of corn crops?

Thirty-two answers. Thirty negative. Two affirmative.

Ammoniacal Salts.—Ammonia is a gas or air of a very pungent odour, and very soluble in water. It is composed of 14 parts of nitrogen, combined with three parts of hydrogen, and is one of the most powerful nutriments for vegetables. Upon it rests the value of guano, pigeon dung, urine, breech compost, and the host of artificial manures meant to supplant guano. A mixed solution of sulphate and muriate of ammonia (sal ammoniac) has produced double the quantity of hay off natural meadow, and shewed well-marked effects on the wheat crops. Mixed salts of ammonia appear to act better than any one salt singly. It is probable that no matter what salt of ammonia be added as manure, it can only be serviceable to a plant in the state of carbonate; and the office of the soil is, no doubt, in many cases to convert the salt into a carbonate. Thus, if sulphate of ammonia be added to a soil containing carbonate of lime, sulphate of lime will be formed, and carbonate of ammonia, which then exerts its beneficial property on vegetation. Ammonia has a powerful effect in increasing the growth of cells in plants, and such soft, parenchymatous organs as the leaf. But its effects seem to cease after it has produced herbage: for in grain crops it has no tendency to make the ear fill more or weigh heavier. Hence, if used as a manure to corn crops, there will be an absolute increase of straw, and a relative diminution of grain: but still the action is beneficial.

The chief ammoniacal manures have been already treated of; the others are of lesser importance. The beneficial effects of soot is due to the sulphate of ammonia it contains. The liquor of gas-works contains a much larger quantity, and in localities of large towns can be had so cheap as to render it desirable to the farmer. It should be laid on with a water cart.

CHAPTER IV.

ROTATION OF CROPS.

It has been shewn that plants abstract a quantity of mineral ingredients, which, when the plant is burned, constitute the ashes. The amount and nature of the substances abstracted have also been given. If crops be raised frequently off ground, without restoring any thing back by manuring, it is found that the harvest gradually diminishes; and, after a certain period, it will be found that the produce in seed, which was originally eight or nine times the amount of what was sown, is reduced to thrice, or even twice its amount. The fertility of the soil is gradually diminished, or it is exhausted, as it is termed. It has been long known that this exhausting power, although exercised by all crops, yet varies very much with individual ones. It may be safely said, that every plant diminishes the fertility of the spot on which it is grown, especially where no portion of it is returned to the ground.

Farmers admit clover to be an ameliorating and not an exhausting crop, which appears contradictory to what has been just said; but this crop grows more at the expense of the atmosphere than of the soil; but even it is exhausting, if it be altogether cropped off without returning any. If, when two crops have been taken away, the residual stems and roots be turned into the soil, it is then a restoring crop. In other words, by sacrificing what would produce a third cropping.

All crops then exhaust a soil, and the whole art of manuring is, to return the ingredients and restore the soil to its fertility, whereby the same crops can be again grown. And if, as Boussingault has well written, we could procure an unlimited supply of manure, and labour cheap, there would be no necessity for following out any system of rotation—there would be no fear of want of manure—and the business of the farmer would be, to calculate the probable value of his harvest against the expense of manure and labour. This is exactly what takes place in gardening, but on large farms it has been found, that too large crops cannot be raised off ground, without the outlay more than counterbalancing it. It has been found necessary, then, to adopt some regular system, and instead of additional manure, to alter the crop each year, and this system has been called the "Rotation of Crops."

When ground has been brought into "good heart" to render it permanently so, after every succession of harvest, it will be necessary to add an equivalent of manure. And looking at the subject in a chemical way, it may be said, that the produce which can be taken away without injuring the soil is the organic matter contained in the harvest *minus* the organic matter contained in the manure; this last must be returned under some form or other to the ground.

In densely populated countries, where the value of land is high, it is desirable that the soil should furnish as much nutritious matter as possible; and that corn crops should follow each other rapidly. This could be accomplished every year by manuring, but weeds and noxious plants rise so rapidly, and can be got rid of only with such great difficulty, that it was found too troublesome to follow.

The use of clover has been one of the greatest improvements in agriculture, and, to a great extent, has done away with fallowing, and so far from exhausting, adds new fertility to the ground, so that an abundant corn-crop is raised after it.

It has been stated by Brugman and Macaire, that the roots of plants throw out certain matters which are hurtful to other plants, and which they called excretions; and this opinion has been taken up by De Candolle, who formed on it a theory of rotations. He supposed that those matters or excretions, if left to remain in the soil, could not afford nourishment to the same crop, but, on the contrary, must be injurious; while if a different crop be planted, it will make use of those matters for nourishment. Of this it may be said to be ingenious but not true. It takes for granted, that there is such a thing as an excretion from the roots of plants, which later observers have never been able to discover; and also, it supposes an occurrence, of which there is no means of arriving at the truth or falsehood, by our present means, namely, the power of plants to assimilate vegetable excrements.

Nature herself, in her operations, follows a system of rotation. When a forest of oak is burned down, it is followed by pines, and beeches will be followed by birch.

Under the old farmers' habits, the land was generally cropped with grain till it was quite poor, and it was then allowed to rest or gain strength by natural meadow. But this is a practice which every Irish farmer will, it is to be hoped, avoid, as by it are only produced weeds and rubbish, which will be an eternal source of torment afterwards, and half starve any poor animal put out to feed on it. In fact nothing can be worse than this practice.

It is an acknowledged fact, that while, generally speaking, corn-crops thrive after green-crops, each corn-crop has its particular green-crop, after which it thrives best. Thus, after turnips, barley succeeds; after grass, oats, after potatoes and beans, wheat, and a good six years' rotation is:—

1. Wheat.
2. Turnips.
3. Barley.
4. Seeds.
5. Oats.
6. Potatoes.

Neither the theory of excretion of roots, nor that of special food appropriated by plants, will explain the fact, that land, after a course of cross cropping, with only one kind of plant, will not yield another crop of any kind—it is so worn out. Probably the different modes of cultivation which land receives, produces the necessity of alternating the crop.

A five years' course of rotation is probably the most adapted to the soils of Ireland generally, or if flax be used, a six years' course, thus:—

1. Fallow, or green crop, manured.
2. Corn.
3. Artificial meadow (sown grasses).
4. Pasture.
5. Corn (oats, barley).

This last crop is rarely a good one, and after it, the soil is a little poorer than it was at the commencement of the rotation, hence the necessity for manuring with the first crop. When the soil will allow of green crops, it should be used, if not the naked fallow; this well suits second-rate soils.

1. Fallow, or green crop manured.
2. Wheat.
3. Beans.
4. Barley or wheat.
5. Sown grasses.
6. Beans.
7. Barley or wheat.

Where flax is desirable, the following shift is used:—

1. Potatoes or turnips manured.
2. Wheat or oats.
3. Flax.
3. Clover.
5. Grass.
6. Oats.

It may not be amiss here to mention that on the Model Farm of Glassnevin, under the Commissioners of National Education, and superintended by the intelligent Agriculturist, Mr. Skilling, two systems of rotation are followed. The four-crop system consists of 19 acres laid down in fields of 4 acres, 3 roods each. The five-crop rotation consists of 30 acres in fields of six acres each. It is laid down in these two systems to shew the pupils the practical working of both systems; were it not so the whole would be laid down in the five-crop rotation.

The crops raised by the four-course shift are:

1st year, Mangold wurtzel, turnips, &c.
2nd „ Oats.
3rd „ Artificial grasses, rye grass, and clover.
4th „ Wheat.

The five-crop rotation is as follows:

1st year, Potatoes, turnips, mangold wurtzel, &c.
2nd „ Oats.
3rd „ Grass pasture, some reserved for hay.
4th „ Italian and perennial rye grass and clover.
5th „ Wheat or barley.

This is well suited for light soils, and well adapted for raising food for cattle; the four-crop shift is better suited for strong, heavy soils, able to bear much cultivation.

The three-crop shift is what is adapted for small farms close by a market town, inasmuch as more cattle can be kept on the same quantity of land than by any other rotation, there being two green crops and one grain crop, viz.:

1st year, Potatoes and turnips.
2nd „ Wheat and barley sown down with grass.
3rd „ Cutting grass.

The whole art of adopting a good system of rotation depends upon suiting the crops to the nature of the soils, and varying them with each other, so that while the greatest amount of produce is raised off the ground, still that the soil shall not suffer to an undue extent; thus, after cropping corn off a soil, a quantity of phosphates and nitrogen has been abstracted; returning the straw in the shape of dung restores the salts abstracted, while the nitrogen may be returned by growing green crops; and these additions can be made while a crop of food is actually being taken from the same soil, thus saving the loss arising from a naked fallow.

CHAPTER V.

ON THE IMPROVEMENT OF SOILS.

When we treated of the constitution and properties of the different kind of soils, and took a slight sketch of an artificial rotation of crops, we explained most of the processes which the agriculturist carries on for the improvement of his ground. Besides these, there are a few other operations essential to the fertility of some lands, and by the aid of which, even the best may be made to increase its produce. It should never be forgotten, that the management of a farm is a branch of art, strictly chemical, and which can never advance to the desired perfection, without an intimate knowledge of the science on which it is founded; it may, like many other acts, progress to a certain point, and remain stationary, and up to that point it has at present arrived, but to advance beyond that, as the increased population and diminished price of produce require, calls for the entire devotion of minds long addicted to science, to explain the hitherto hidden secrets of nature, and point out the path which may lead to success without the chance of failure.

Professor Johnston remarks that the first business of any person engaging in the practice of agriculture should be to know the nature and quality of the land he possesses, the ingredients of its surface soil, both mineral and organic matters; the nature and extent of the sub-soil; the climate, elevation, and aspect. He should learn the usual amount of crops his land could raise; the usual routine practice of the district, and if any local difference exist from other practices, to ascertain its cause. He should consider seriously in his mind what are the plans most proper to be adopted, drawn from the examination he has made of his own soil; he should balance any conclusion he may arrive at with the practice as at present carried on in his neighbourhood, and if differences exist, to weigh well the reasons for the popular practice, and, if not satisfactory, to reject them; for it is a matter of regret to be obliged to state, that too many of the practices originated in ignorance, and are perpetuated by custom and reverence for antiquity, which should long since have been exploded.

The chemical principles on which soils may be improved have been treated of; the mechanical or physical principles require a few words. They are ploughing, draining, and mixing, and irrigation; which latter partakes of a chemical as well as a physical principle.

To ensure the fertility of soils, these physical principles must be attended to; they are no less essential than those practices termed chemical, which we have just treated of at large: and, in point of order and time, they should be the first attended to. Of these *draining* is the first and most important step to be taken, for if the soil be not deprived of its superfluous moisture it can never either be warm or nutritious to the crops grown on it. Although it may have all the benefit of the sun's rays, it can yet derive but little advantage from it; for before the ground can be warmed, the extra water will require to be evaporated: and, in carrying on this process, all the solar heat will be appropriated. A second necessity for draining arises from the fact, that as the food of plants requires to be in a fluid state to enter the roots, if too much water be present, there is a danger that the soluble nutriment may be washed away into the lower or sub-soil, or it may be so diluted as to afford only a sparing support to the rootlets; but when the soil has been drained, it imparts more warmth to the plants, and the necessary changes go on in the interior of the stem.

When a soil has been drained, much of the difficulty of its being worked has been removed; it is no longer so close and tenacious, but allows of the air to permeate it readily to a great depth, by which means a healthy growth of plants is accelerated, and the roots can find their way in every direction.

The vegetable matter in the soil decomposes more rapidly, less acid principles generated, and carbonic acid is formed in larger quantity where the surface ground is drier. And where the soil is clayey, with a sandy or gravel subsoil, draining the surface will remedy it. But on sandy surface, soils with stiff sub-soils, unless the sub-soil be drained, the soil will always be moist and cold. Springs are to be dried by cutting under drains of sufficient depth to intercept them, and open drains to carry off the surface moisture. Where oozings of water occur, indicated by a darker colour of the soil, or the production of a coarse herbage, one drain of large dimensions will be of more effect than a number of small ones. The fall of the drains should be gentle, lest the soil be carried down and the drain choked up below.

Sub-soil draining, with ploughing, is of inestimable value, for the ground rarely ever hardens again after being so broken up; air and water circulates freely through, and the harvest can be raised off it much earlier.

The advantages derived from ploughing are, that it loosens the lower clay, and allows the water to pass down freely; it allows the air to pass in carrying carbonic acid to the plant, and oxygen to oxidize the ferruginous principles, which are so injurious on most wet lands; it causes the decaying vegetable matter to pass through its changes much quicker.

Mr. Smith advises the subsoil ploughing to be used a year after the land has been thorough drained, in order to ensure that the clay be dried before its application. Deep ploughing brings new earth to the surface, and replenishes its ingredients.

The mixing of soils, in many instances, increases its fertility, as where clays are very stiff, mixing it with fine sand opens its pores, and allows the air to penetrate it. To sandy or peaty soils clay is a valuable addition, by giving cohesion and solidity to the mass, besides adding earthy ingredients not previously existing in the soil; the addition of lime, marl, and shell sand acts physically, by dividing clayey soils, or rendering sandy ones cohesive; but their chief action is chemical, and has been treated of under their several heads.

Although, as has been just stated, that water lying on a soil is highly injurious, yet the frequent addition of water to ground is highly beneficial. This practice, which is of great antiquity, is much neglected in Ireland. By means of *irrigation*, which involves very little trouble or cost, large crops of hay and fine pasturage may be obtained. Running water conveys food to plants; it warms soils in winter, and cools them in summer; it destroys certain weeds. As we have stated before, it is especially adapted for sandy soils. The best seasons for irrigation are early in winter and in spring—flooding the ground for fourteen or twenty days, and leaving it dry for one-half that time, and alternating this practice for some months. When any noxious or ferruginous ingredient exists in ground, it is removed by a plentiful supply of water.

The burning and paring of land is a process much carried on in the western parts of Ireland; concerning the general effect produced upon ground by it much obscurity prevails, and in some cases it exercises such injurious tendencies that the burning of land without the express permission of the landlord is prohibited by Act of Parliament: in many cases it is used as a substitute for sufficient manure, and a proper system of rotation.

When soil is burned, the vegetable matter of the plants is driven off, while the ash remains mixed with the clay of the sod. It is analogous then to a dressing of wood ashes, or peat ashes, and its effects are chiefly due to the alkaline salts it contains; it destroys the roots of weeds, and renders the clay more open. It is especially adapted for boggy surfaces, and is one of the cheapest modes of reclaiming; but on good dry land, it should never be practised, as it is terribly exhausting.

THE END.